

SFWRENG 3K04

Part 3 Documentation - Testing

Group #12

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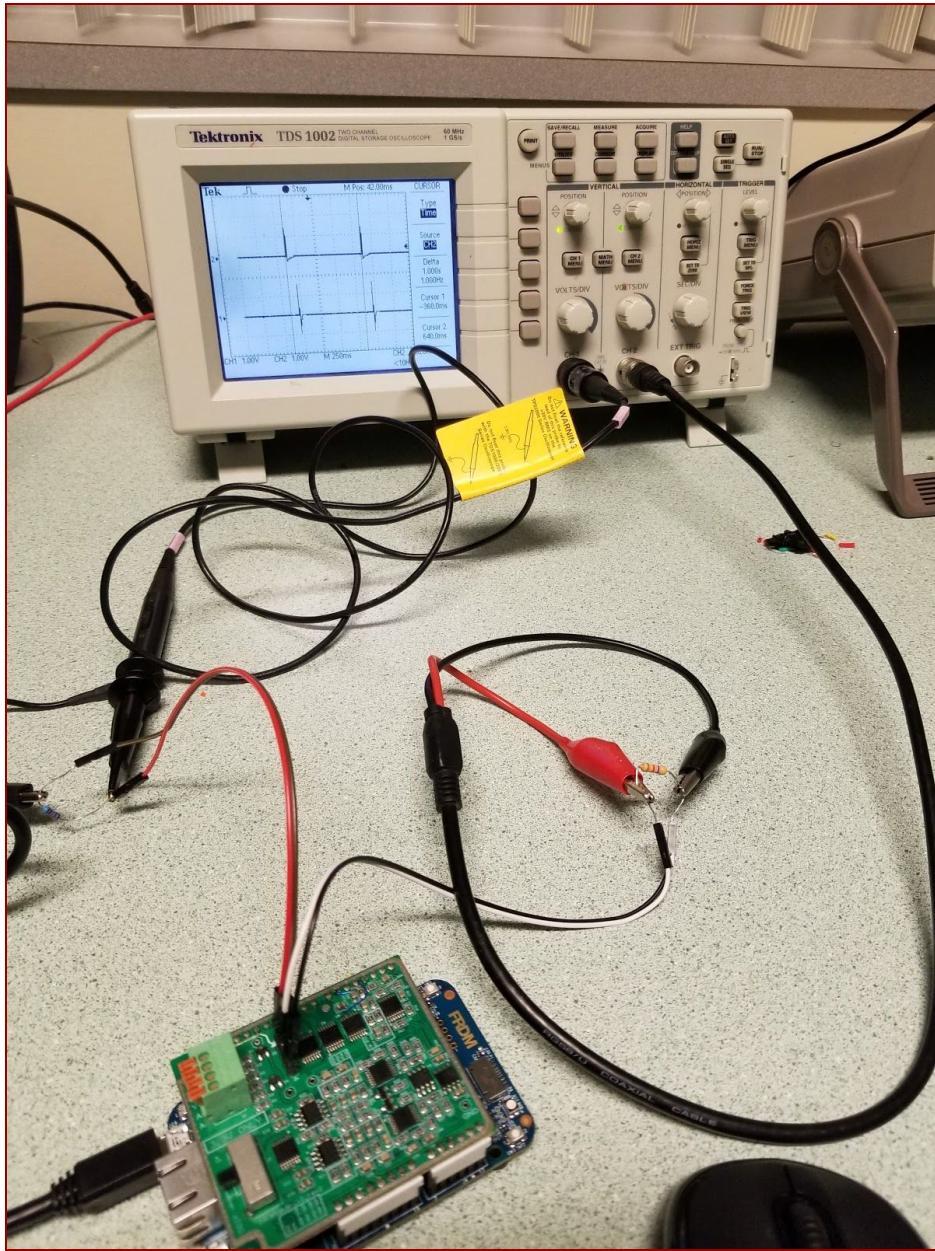
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Overview of Testing Environment

Most testing was carried out using a separate oscilloscope setup with the pacemaker receiving parameters from the DCM to prevent having to re-compile with each test case. This setup is shown in Figure 1 below:

Figure 1: Oscilloscope Setup



Resistors are placed across the atrium and ventricle pacing pins, with oscilloscope probes across the resistors. Of course, this setup does not allow for testing of the pacemaker's response to natural pulses. Thus, inhibiting modes were tested on the labview testbench, though limited access to this setup prevented extensive testing of these modes.

The test cases in this document will be formatted in the following sequence: heading will briefly describe parameter being tested, DCM screenshot to show input values, picture of oscilloscope output, and a

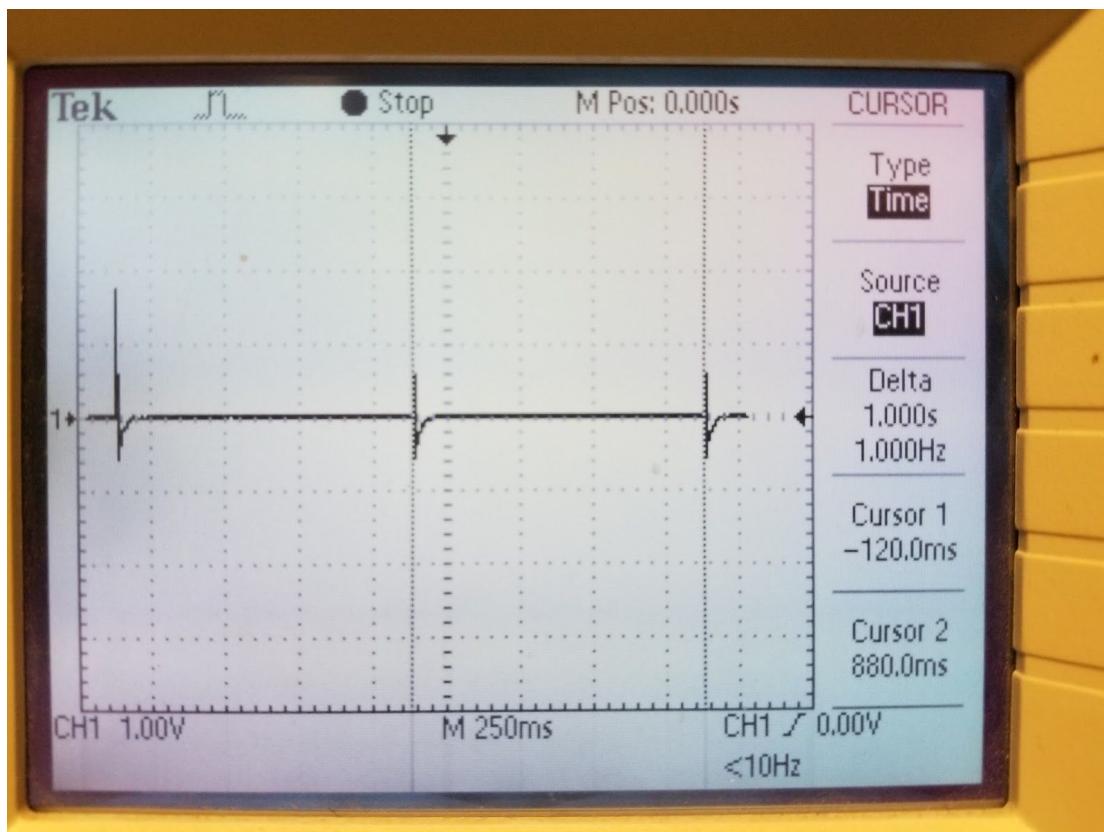
brief discussion of pass/fail based on the expected output. The first test case will typically be a baseline test, then following cases will change only 1 or 2 parameters for comparison.

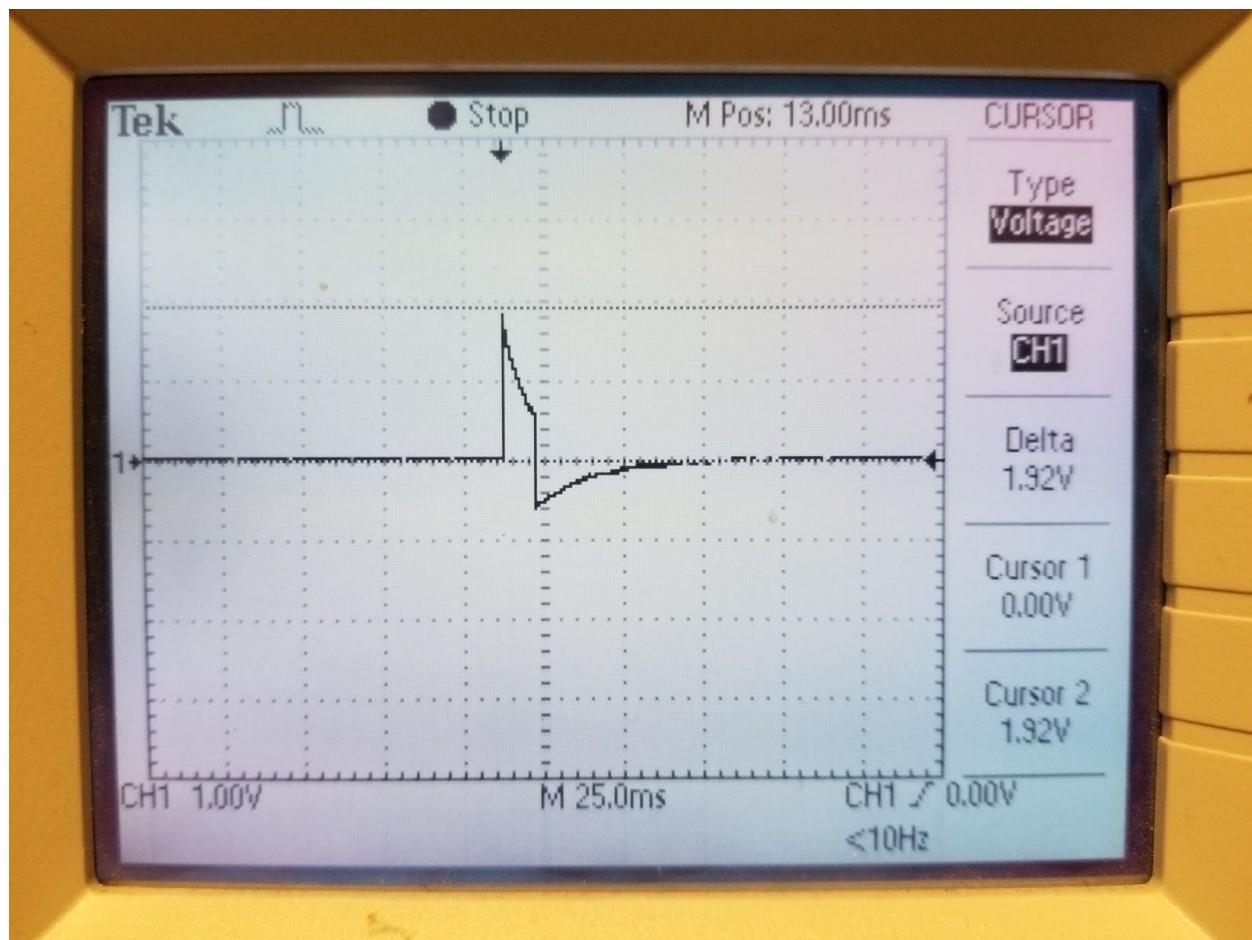
1. AOO Testing

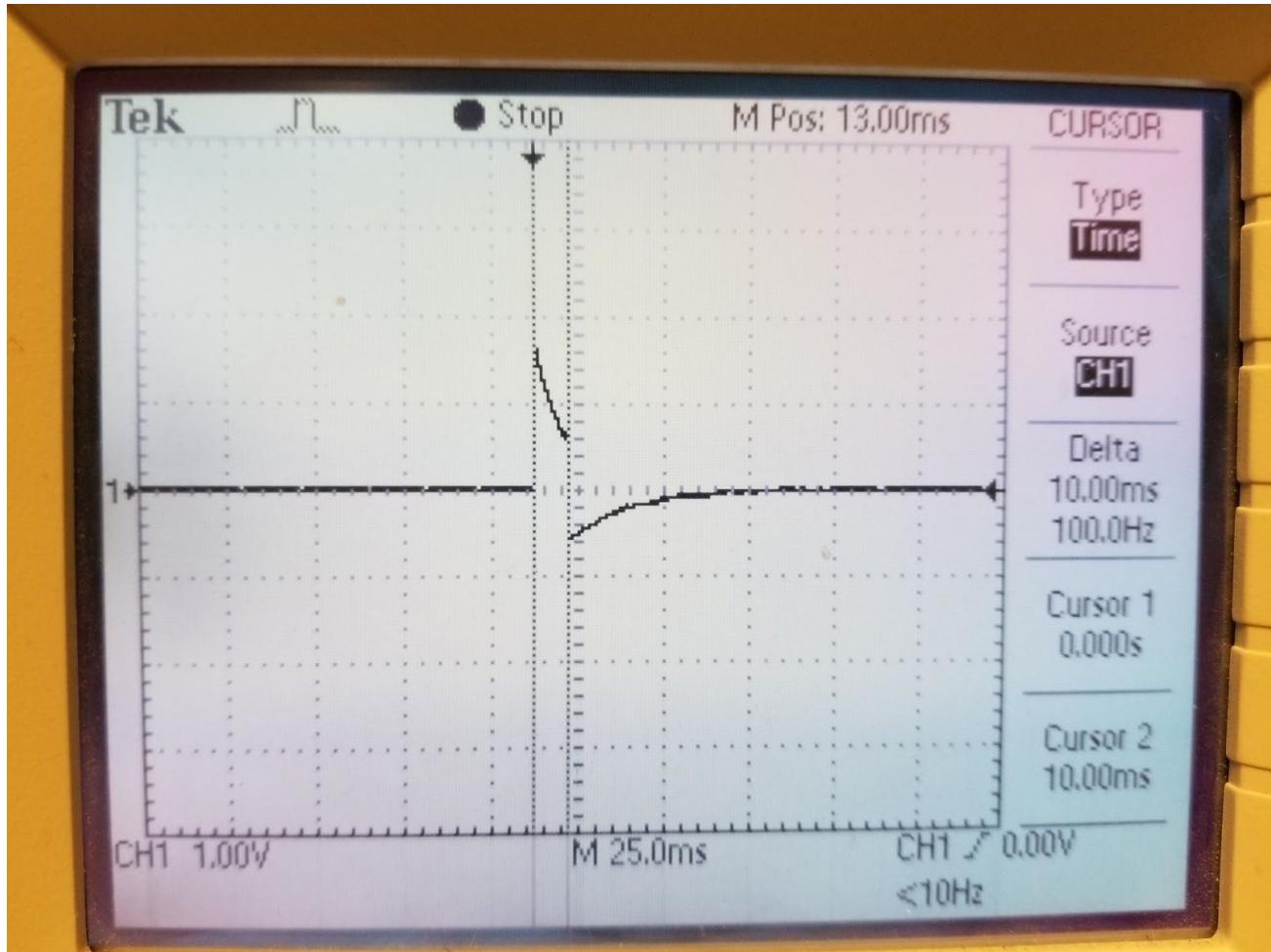
1.1. Test Case 1: Baseline

Pacemaker Interface

AAO	VOO	AAI	VVI	D00	AOOR	VOOR	AAIR	VVIR	DOOR	DDDR
Lower Rate Limit (ppm) <input type="text" value="60"/>										
Upper Rate Limit (ppm) <input type="text" value="150"/>										
Atrial Amplitude(V) <input type="text" value="2.0"/>										
Atrial Pulse Width (ms) <input type="text" value="10"/>										
<input type="button" value="Submit"/>										







Result: Pass. All timing measurements match input values. Amplitude deviated from input by ~4%, but the amplitude output to the scope was heavily dependent on whether good contact was being made between the male-male pin adapter and the Pacemaker Shield, as well as the contact between the pin adapter and the leads to the scope probes.

1.2. Test Case 2: Higher LRL

Pacemaker Interface

AOO VOO AAI VVI DDO AOOR VOOR AAIR VVIR DOOR DDDR

Lower Rate Limit (ppm) 120
50 65 80 95 110 125 140 155 170

Upper Rate Limit (ppm) 150
75 90 105 120 135 150 165

Atrial Amplitude(V) 2.0
0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0

Atrial Pulse Width (ms) 10
1 2 3 4 5 6 7 8 9 10



Result: Pass. Period between pulses matches expected output of 2 pulses per second.

1.3. Test Case 3: Lower Pulse Width

Pacemaker Interface

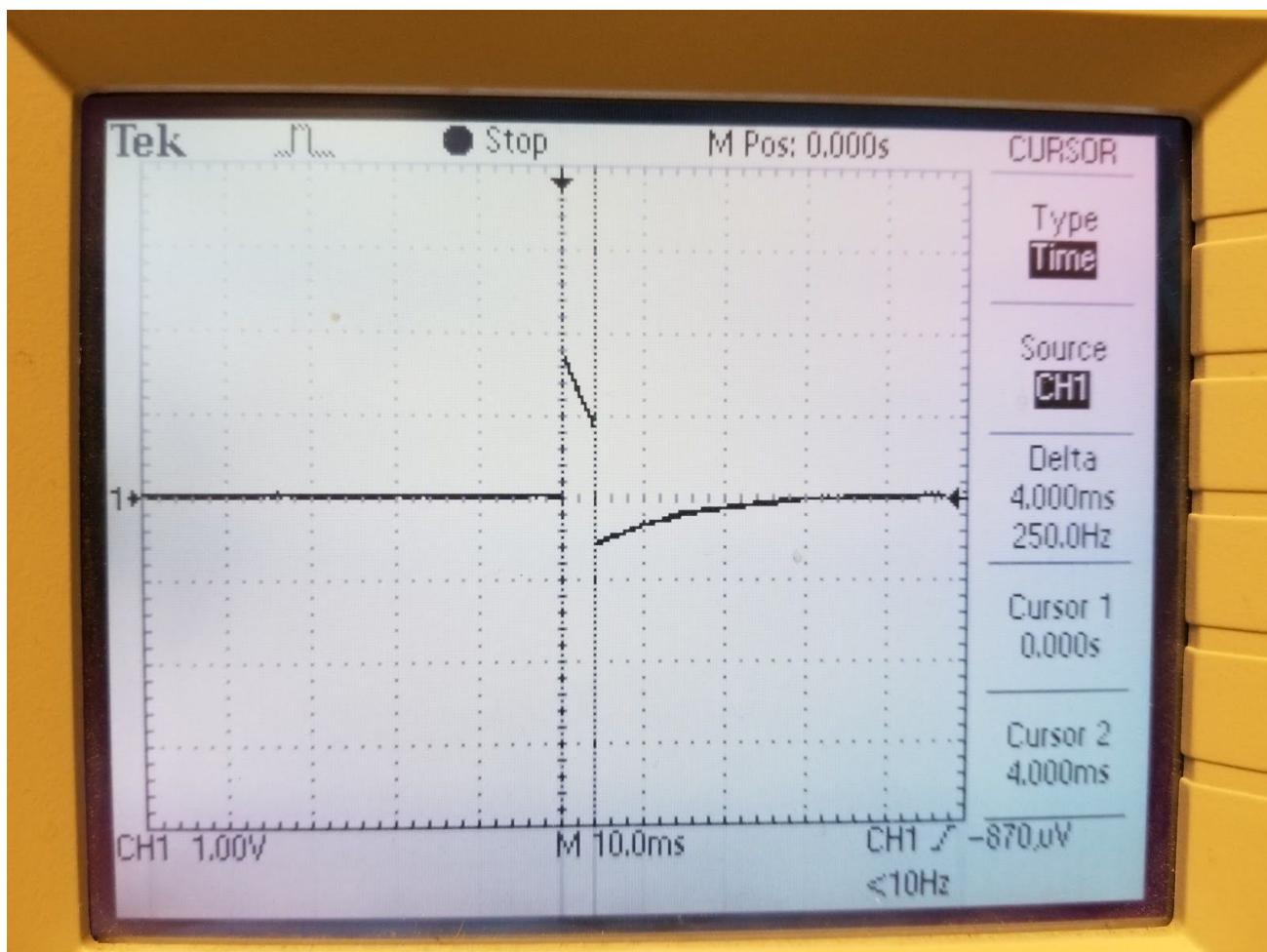
AOO VOO AAI VVI DDO AOOR VOOR AAIR VVIR DOOR DDDR

Lower Rate Limit (ppm)

Upper Rate Limit (ppm)

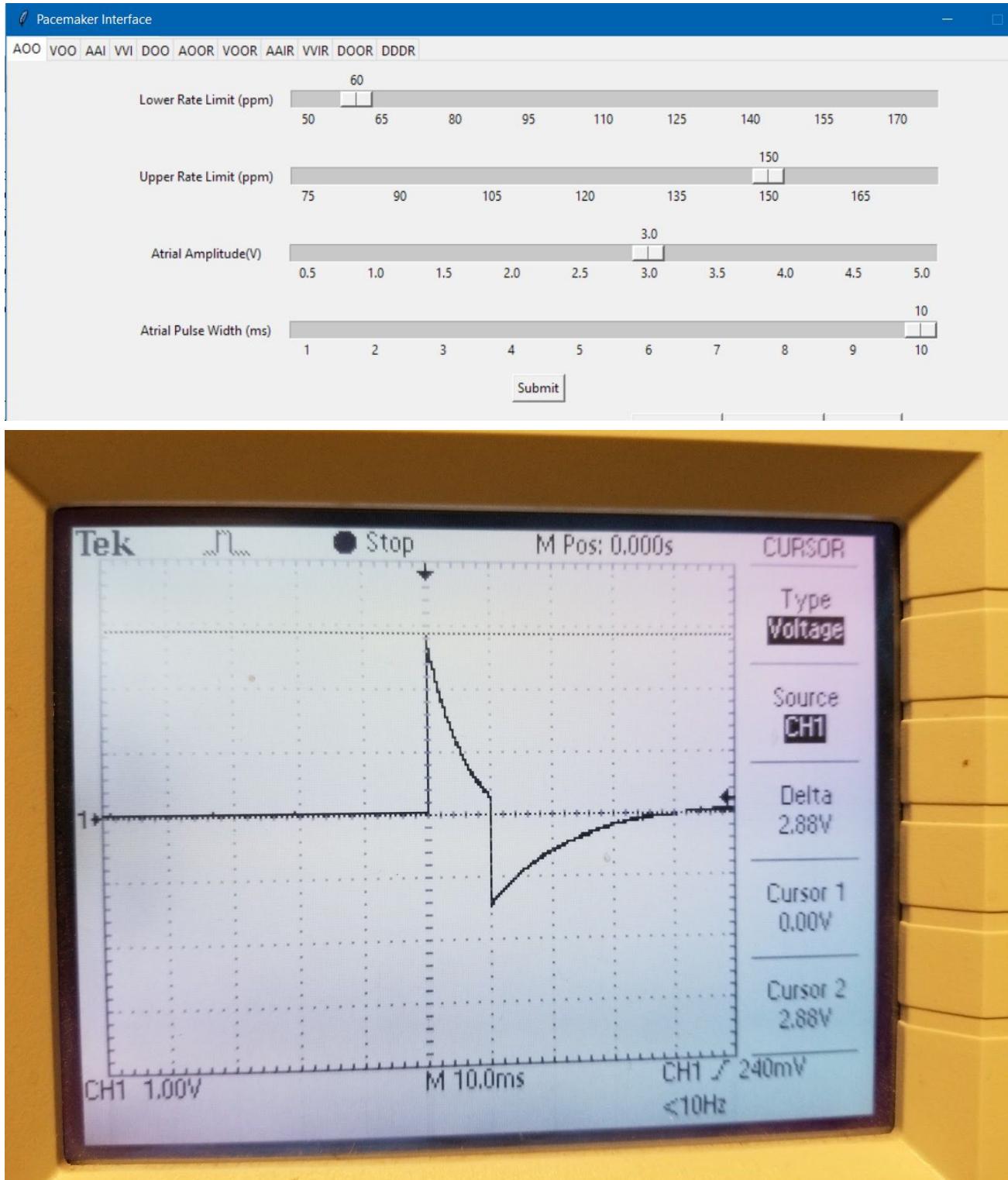
Atrial Amplitude(V)

Atrial Pulse Width (ms)



Result: Pass. Pulse width correctly adjusted to input value of 4ms.

1.4. Test Case 4: Higher Amplitude



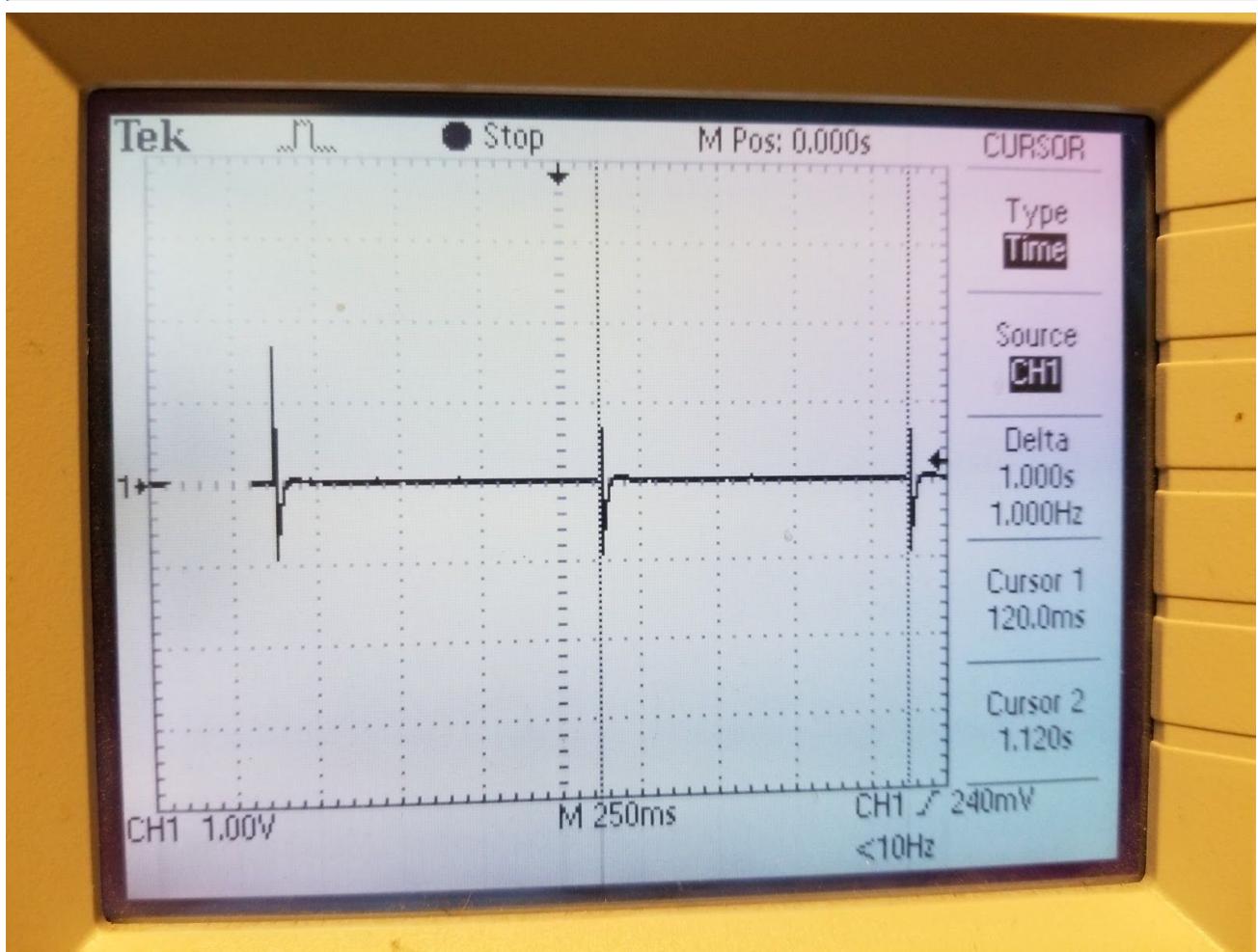
Result: Pass. Output voltage deviates ~4% from input value, but increased by 1 volt compared to the baseline test. Again, amplitude readings depended heavily on contact quality.

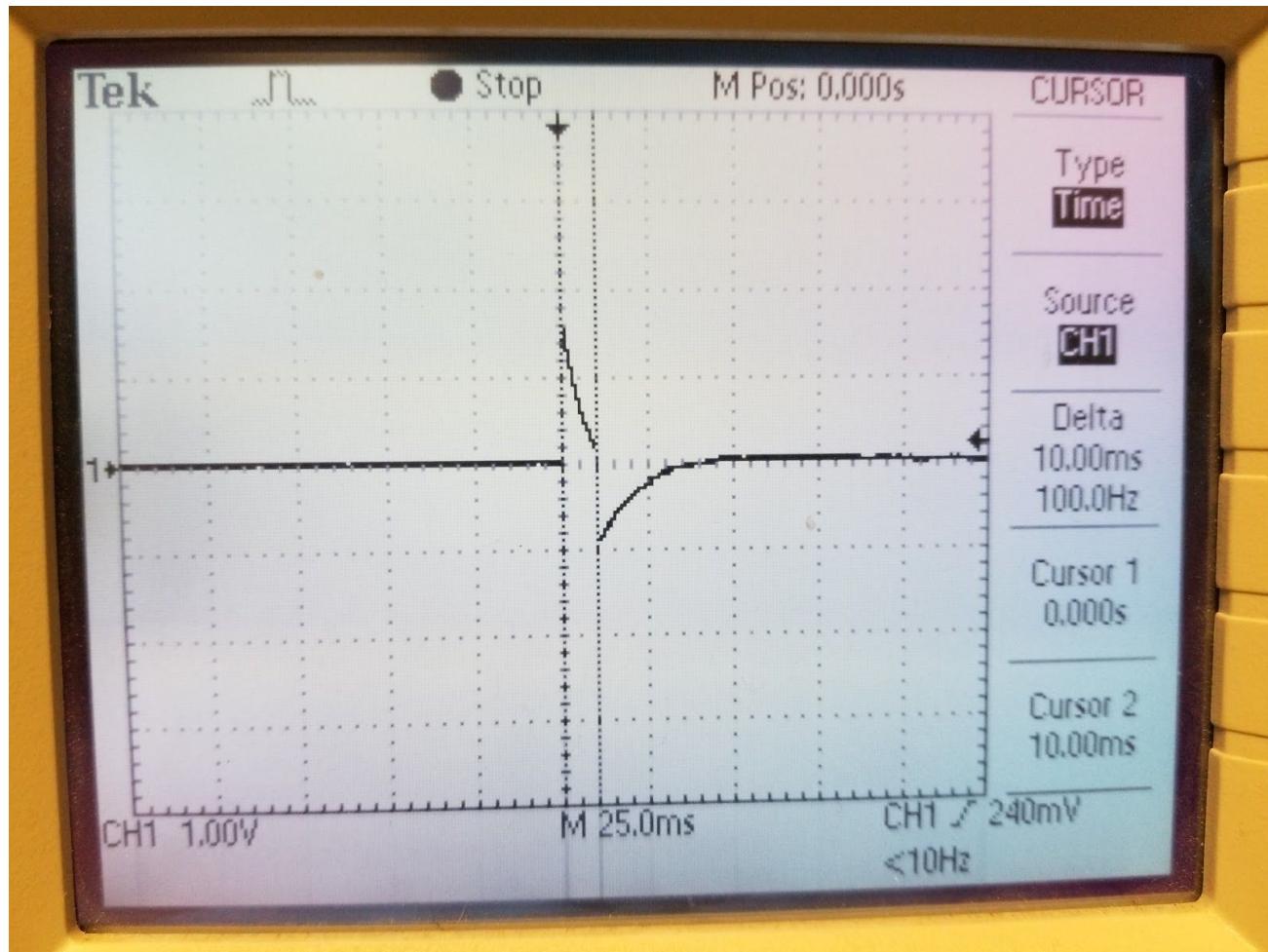
2. VOO Testing

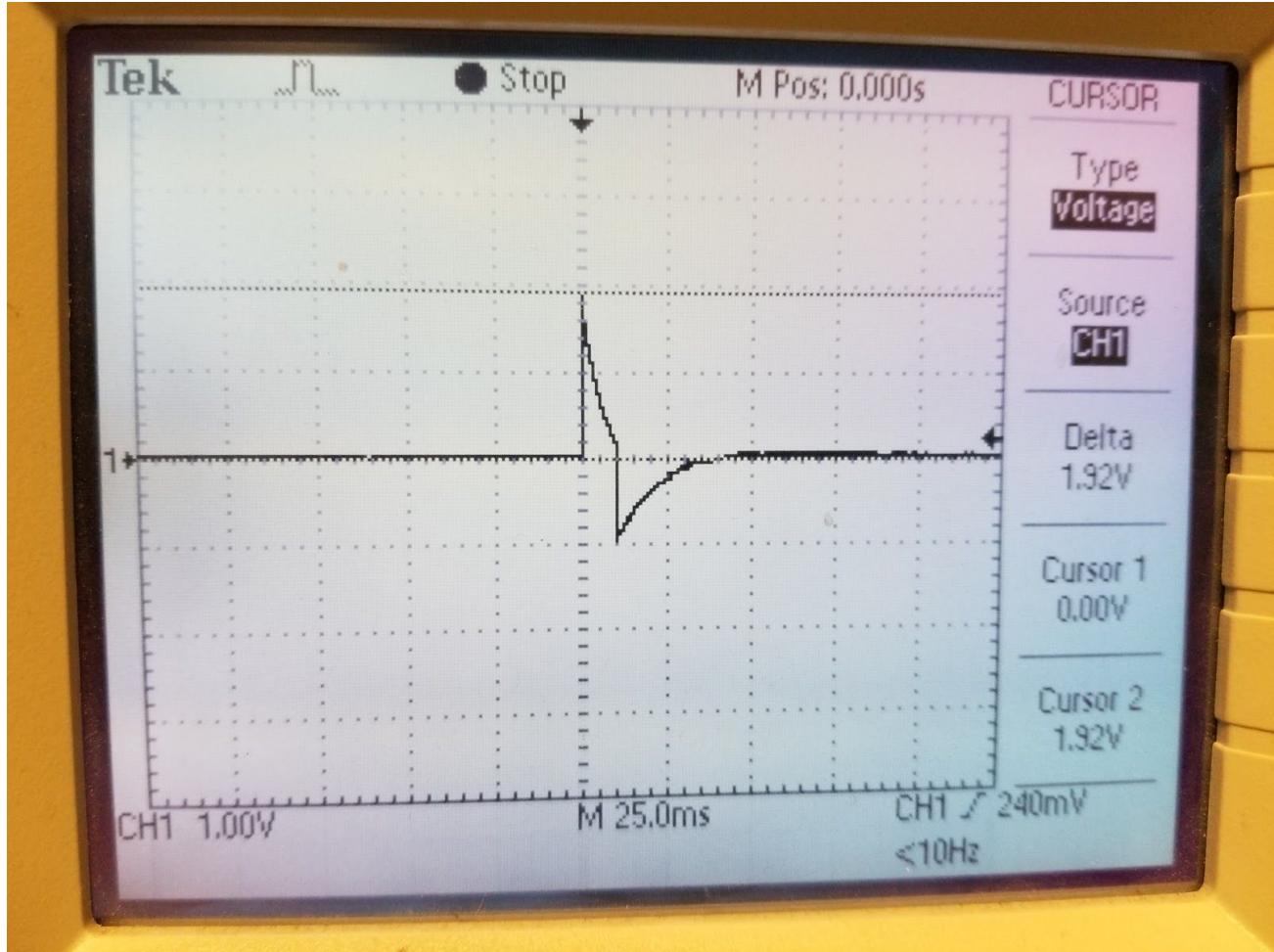
2.1. Test Case 1: Baseline

Pacemaker Interface

	AOO	VOO	AAI	VVI	DOO	AOOR	VOOR	AAIR	VVIR	DOOR	DDDR
Lower Rate Limit (ppm)	60										
	50	65	80	95	110	125	140	155	170		
Upper Rate Limit (ppm)	150										
	75	90	105	120	135	150	165				
Ventricular Amplitude (V)	2.0										
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	
Ventricular Pulse Width (ms)	10										
	1	2	3	4	5	6	7	8	9	10	
<input type="button" value="Submit"/>											







Result: Pass. All timing measurements match input values. Amplitude deviated from input by ~4%, due to imperfect contacts.

2.2. Test Case 2: Higher LRL

Pacemaker Interface

Mode	AOO	VOO	AAI	VVI	D00	AOOR	VOOR	AAIR	VVIR	DOOR	DDDR
Lower Rate Limit (ppm)	50	65	80	95	110	125	140	155	170	90	
Upper Rate Limit (ppm)	75	90	105	120	135	150	165			150	
Ventricular Amplitude (V)	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	2.0
Ventricular Pulse Width (ms)	1	2	3	4	5	6	7	8	9	10	10



Result: Pass. Period between pulses matches expected value of 667ms (accounting for scope resolution error).

2.3. Test Case 3: Higher Amplitude

Pacemaker Interface

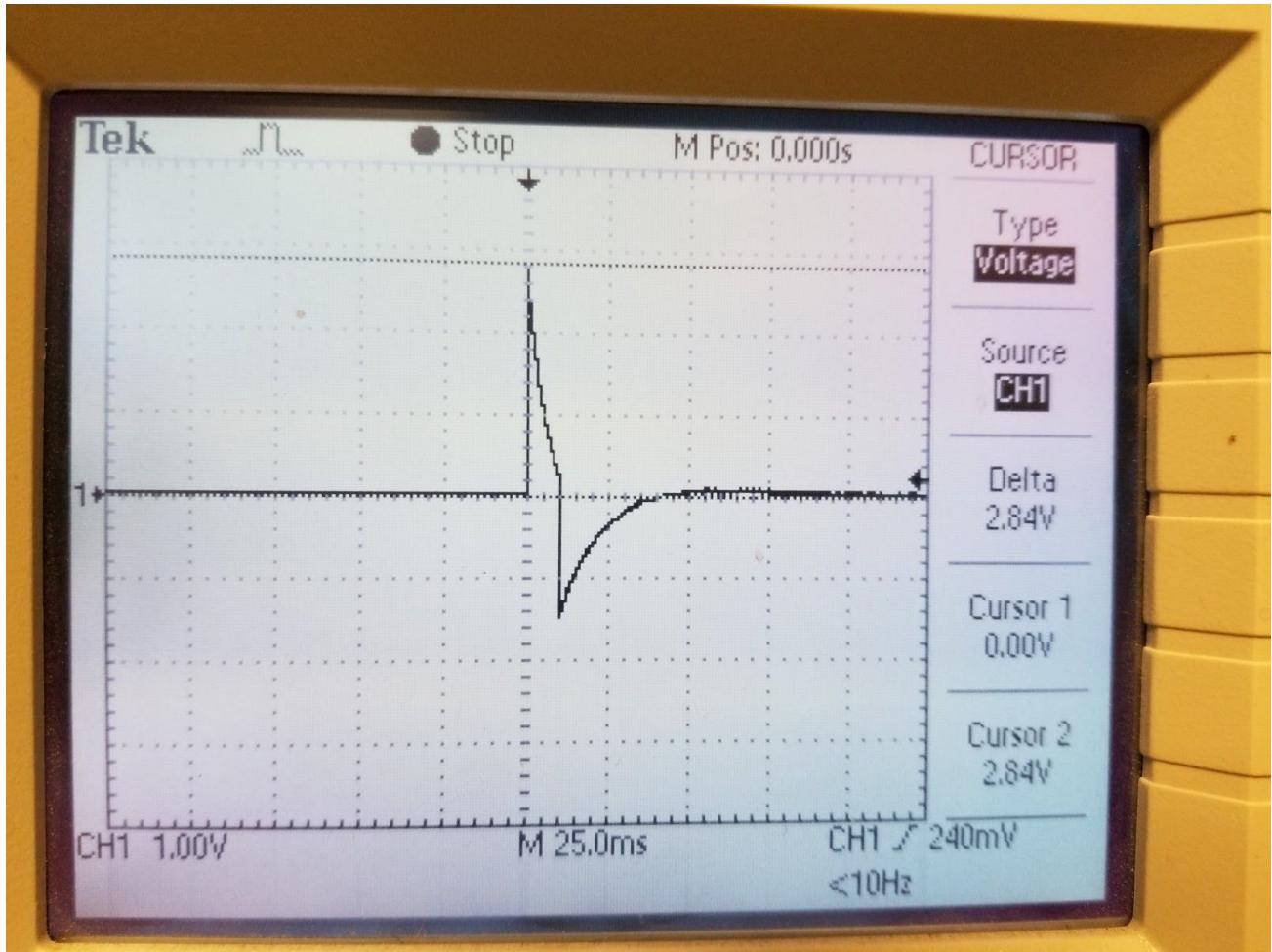
Mode	Value
AAI	
VVI	
DOO	
AOOR	
VOOR	
AAIR	
VVIR	
DOOR	
DDDR	

Lower Rate Limit (ppm)

Upper Rate Limit (ppm)

Ventricular Amplitude (V)

Ventricular Pulse Width (ms)

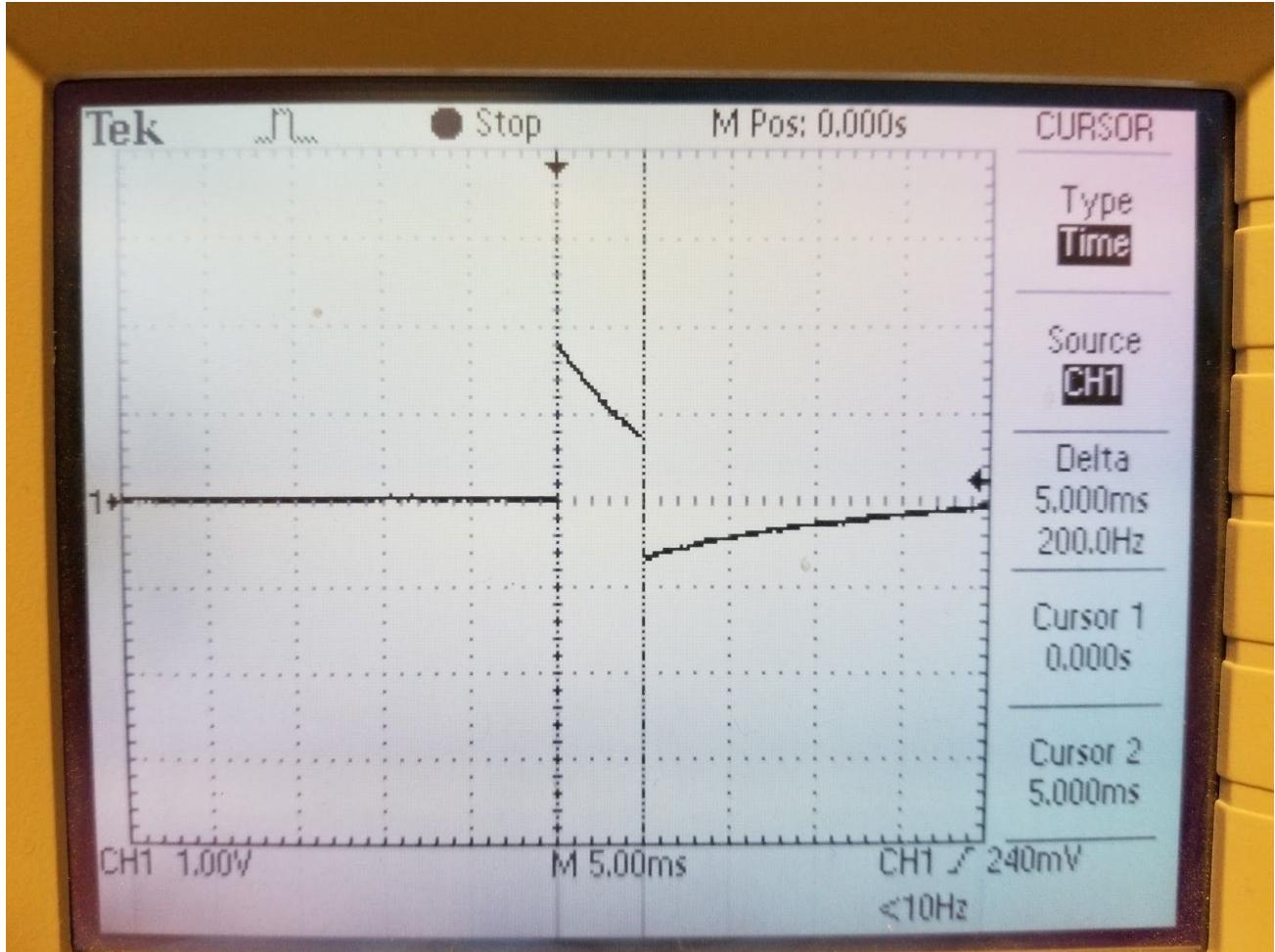


Result: Pass. Output voltage deviates ~5% from input value, but increased by ~1 volt compared to the baseline test. Again, amplitude readings depended heavily on contact quality.

2.4. Test Case 4: Lower Pulse Width

Pacemaker Interface

Mode	AOO	VOO	AAI	VVI	DIO	AOOR	VOOR	AAIR	VVIR	DOOR	DDDR
Lower Rate Limit (ppm)	60	50	65	80	95	110	125	140	155	170	
Upper Rate Limit (ppm)	150	75	90	105	120	135	150	165			
Ventricular Amplitude (V)	2.0	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0
Ventricular Pulse Width (ms)	5	1	2	3	4	5	6	7	8	9	10
<input type="button" value="Submit"/>											

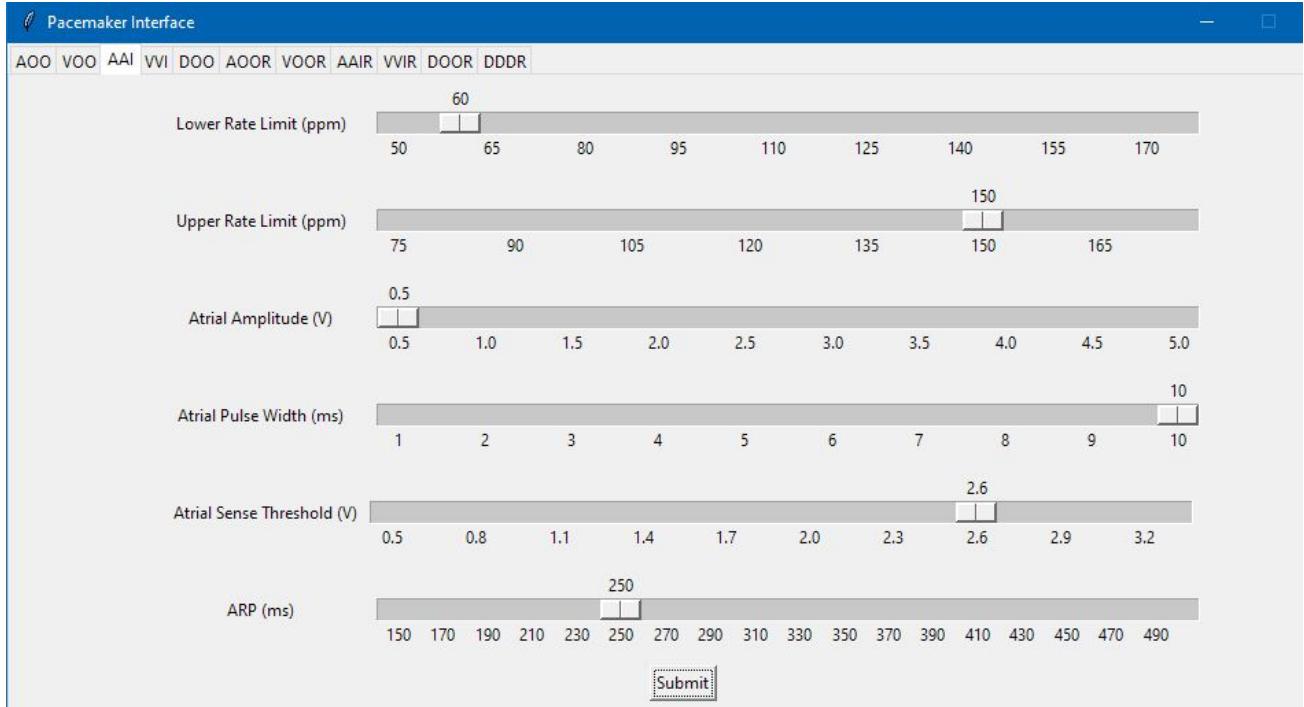


Result: Pass. Pulse width correctly adjusted to input value of 5ms.

3. AAI Testing

AAI testing was carried out on the labview testbench to experiment responses to natural pulses.

3.1. Test Case 1: Inhibiting a Pace

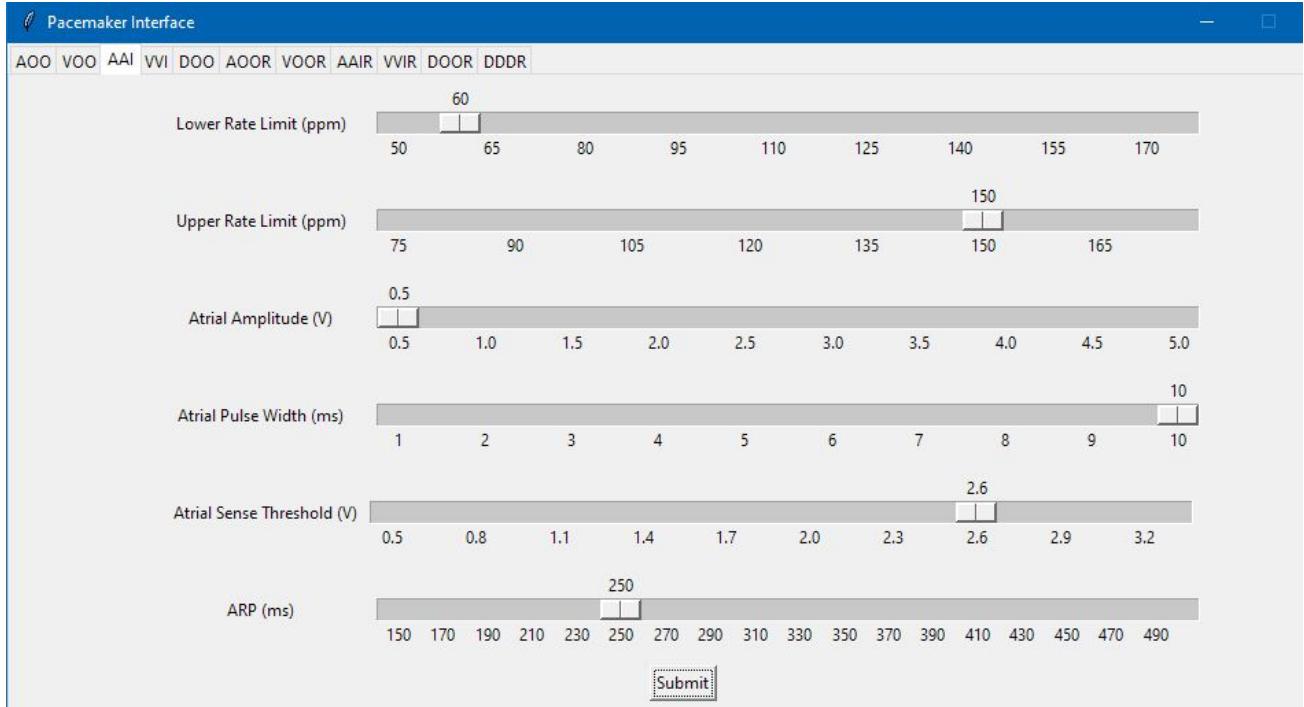


The labview atrial pulse was set to a natural rate of 32bpm.

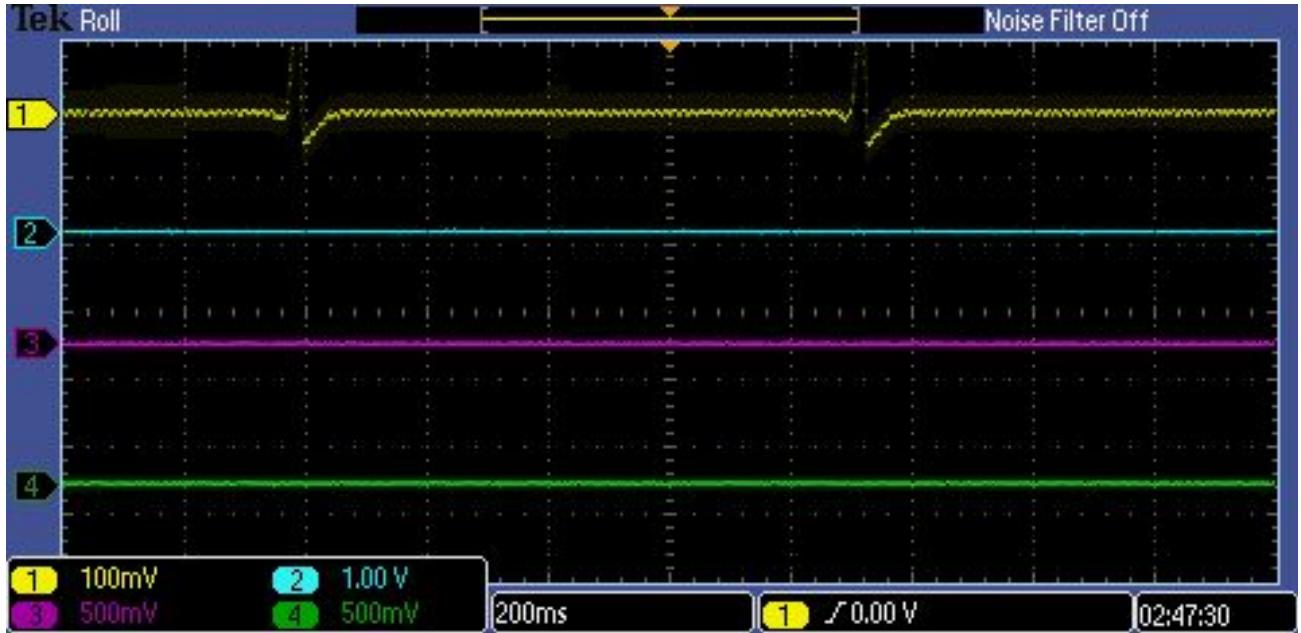


Result: Pass. The natural pulse (yellow) causes the artificial pacing (purple) to delay by one period following a natural pulse.

3.2. Test Case 2: Sustained Inhibition

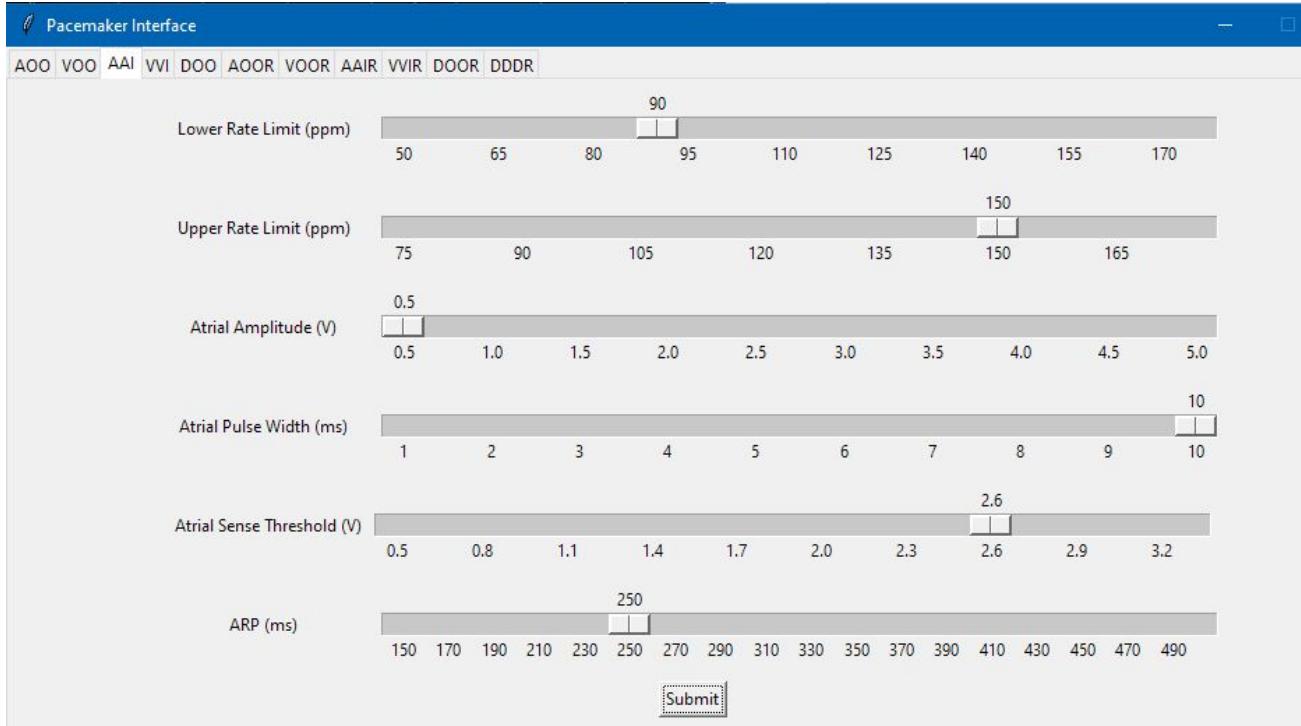


DCM input parameters are the same as test case 1, however the labview atrial pulse was set to a rate of 65bpm.

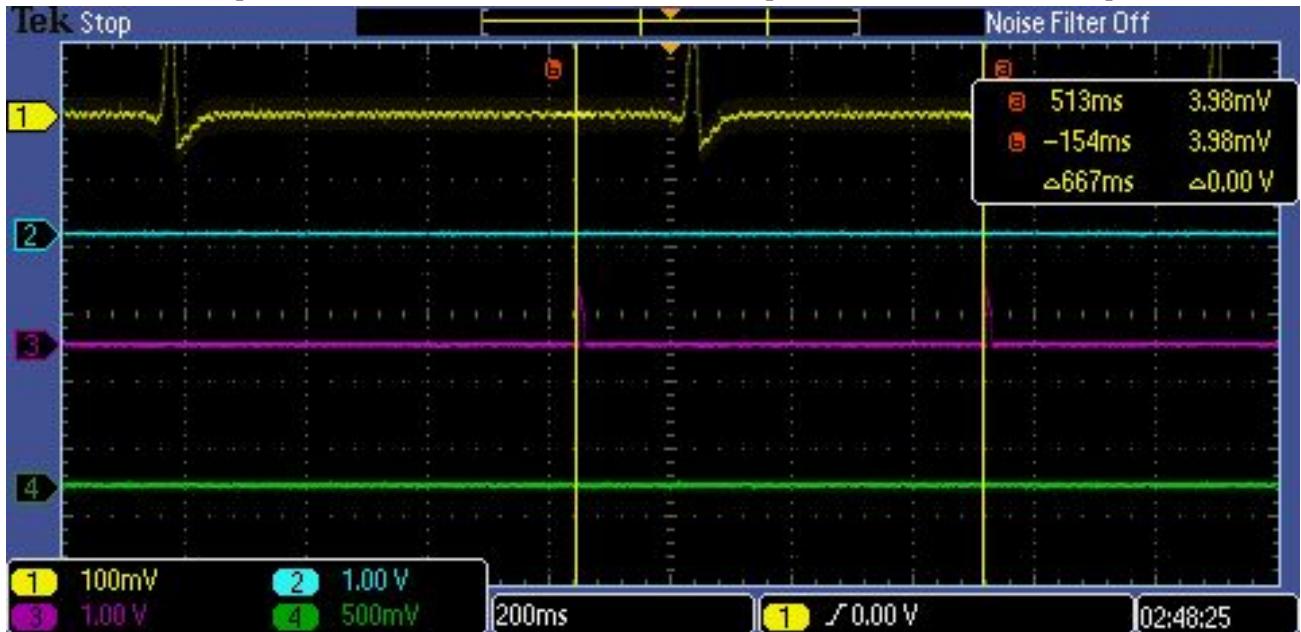


Result: Pass. All artificial paces are inhibited since the natural rate exceeds the artificial pacing rate.

3.3. Test Case 3: Refractory Period



LRL is now 90 compared to test case 1 and 2. The labview atrial pulse was set to a rate of 70bpm.

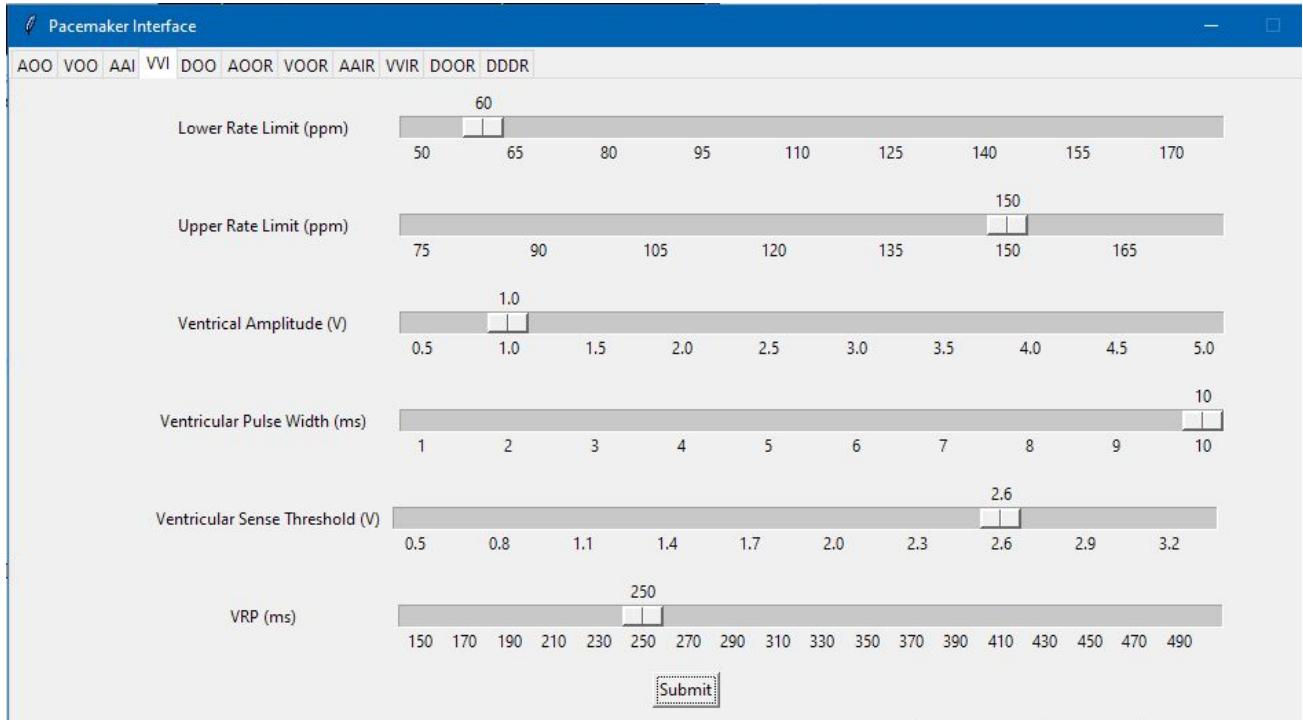


Result: Pass. The natural pulse falls within the refractory period, so the next artificial pace is not inhibited and still occurs 1 period following the previous artificial pace.

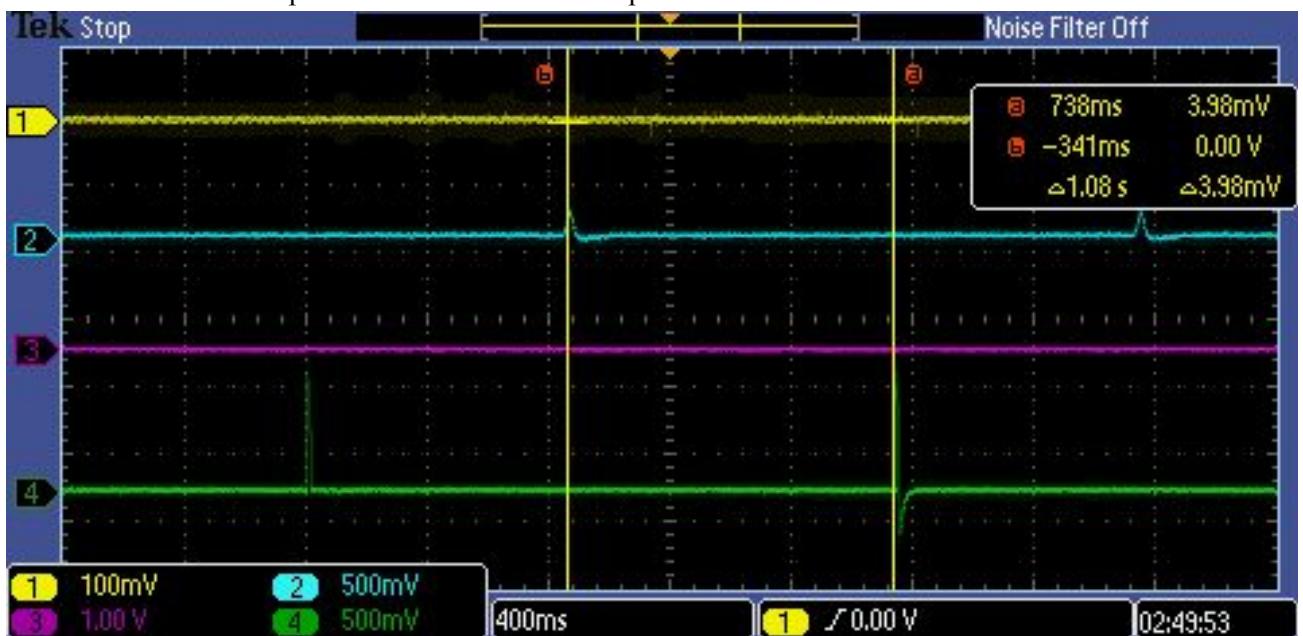
4. VVI Testing

VVI was not tested adequately on the labview testbench due to limited availability during lab time. Moreover, the program had to be tuned following these test results.

4.1. Test Case 1: Inhibiting a Pace

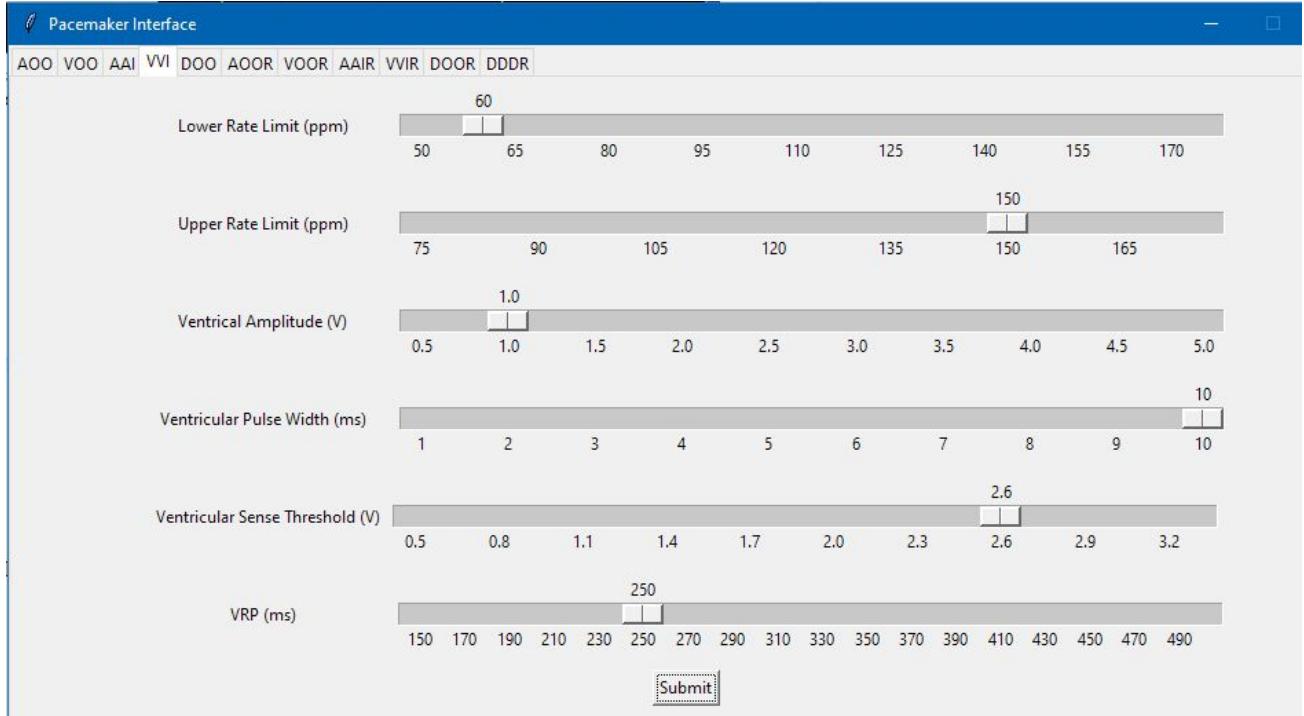


The labview ventricular pulse was set to a rate of 32bpm.

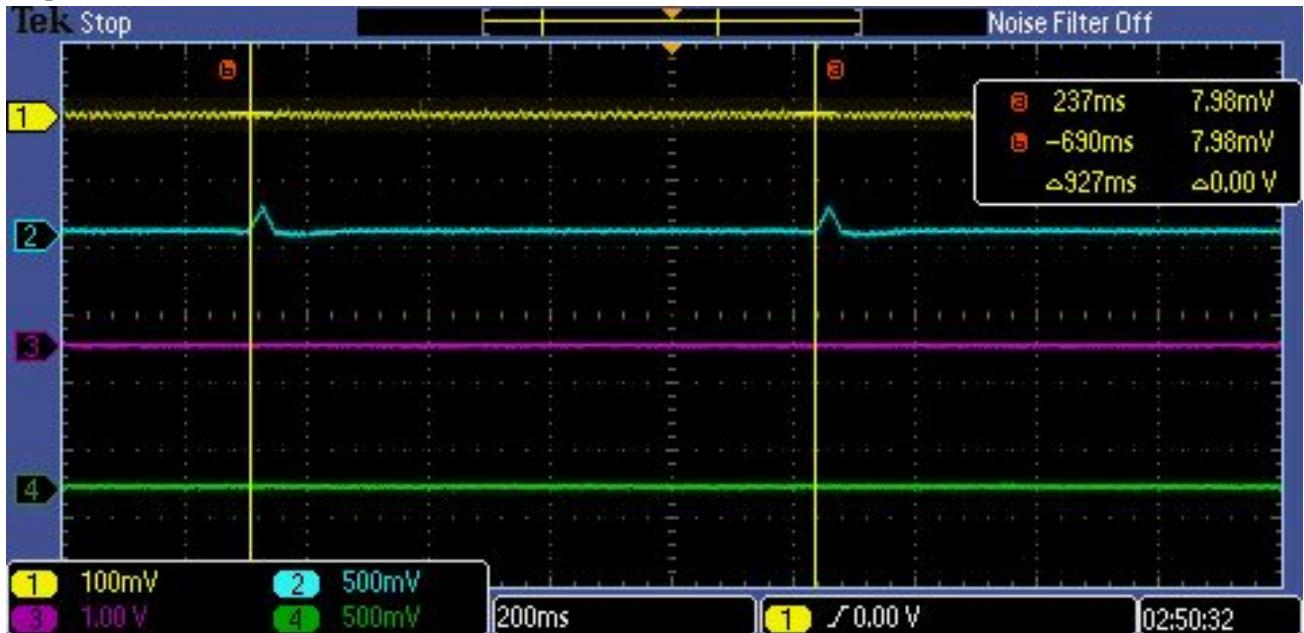


Result: Fail. The pace is inhibited, but the timing does not correspond to one period between the natural and artificial pace.

4.2. Test Case 2: Sustained Inhibition



DCM input parameters remain the same from test case 1. The labview ventricular pulse was set to a rate of 64bpm.



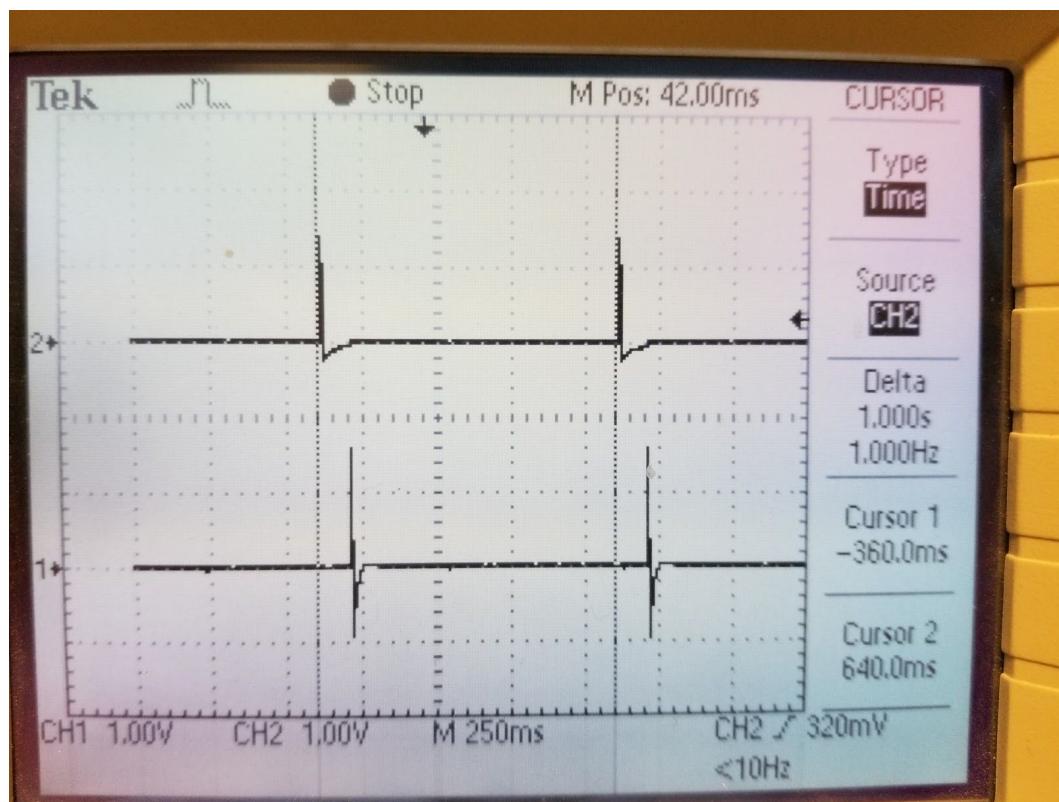
Result: Pass. All artificial paces are inhibited since the natural rate exceeds the artificial pacing rate.

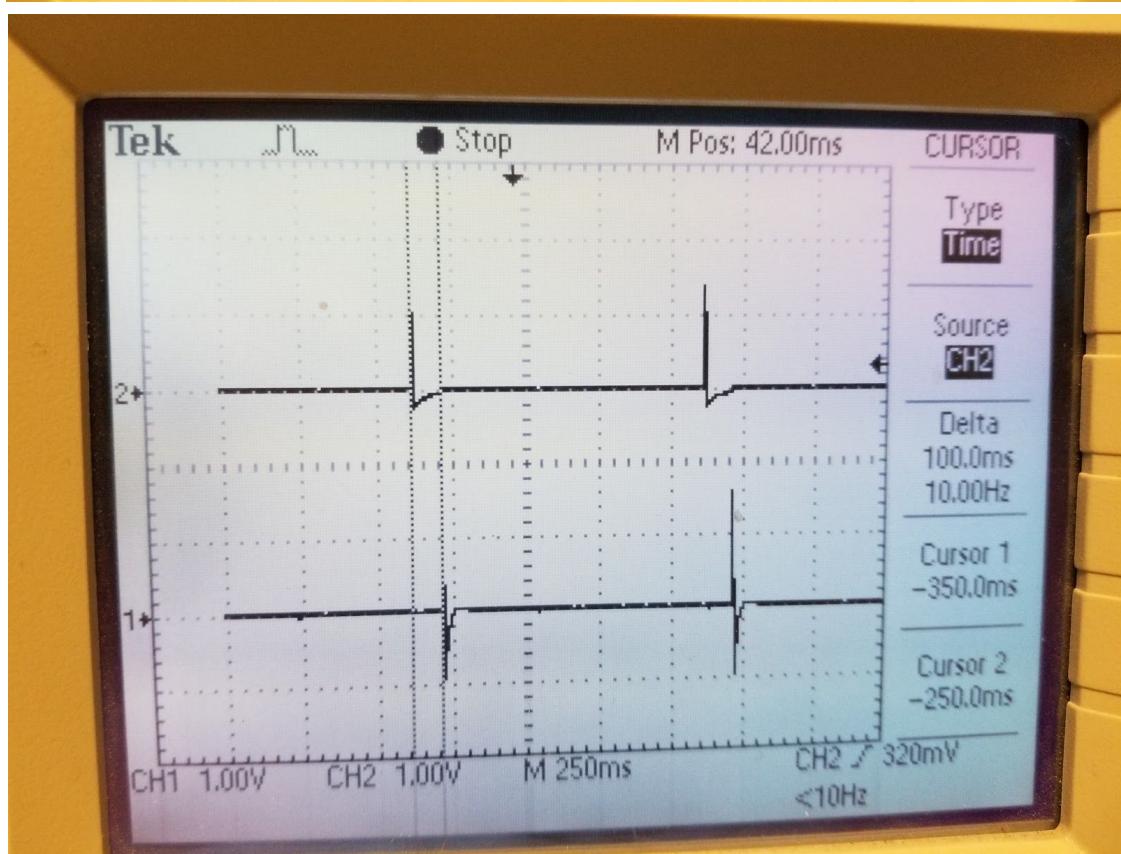
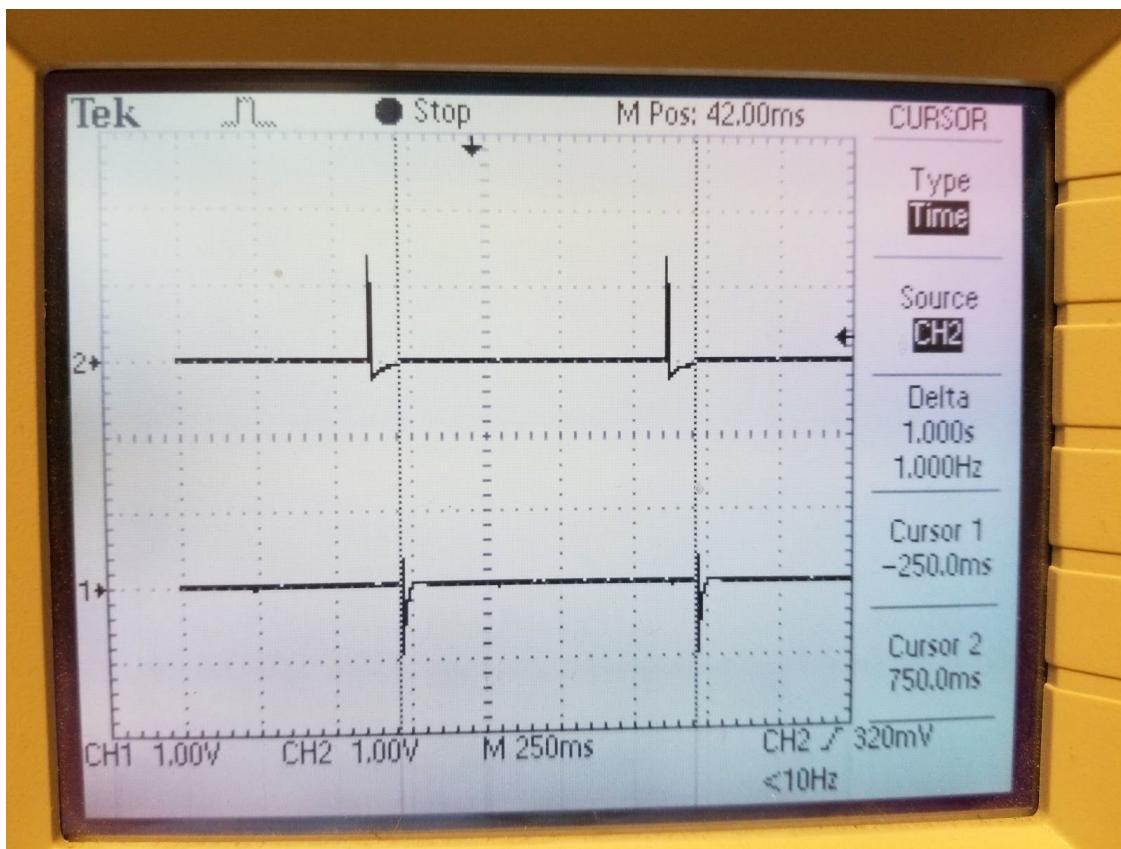
5. DDO Testing

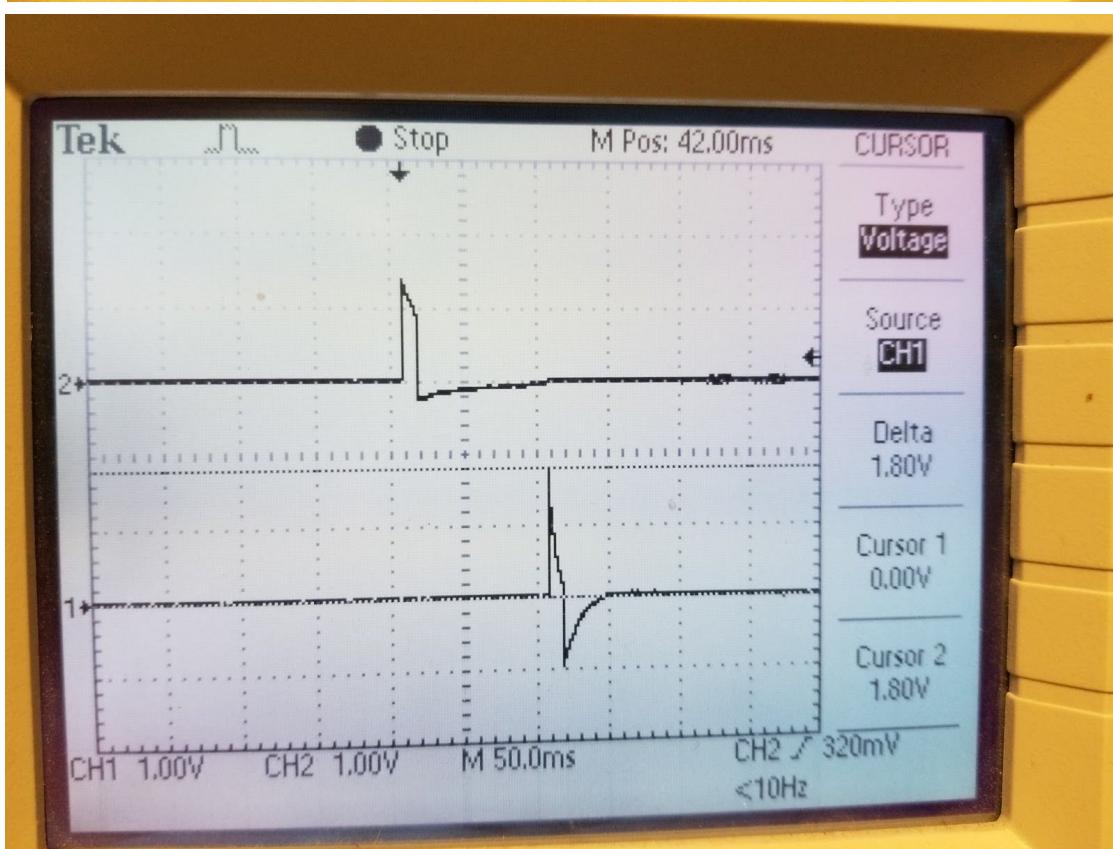
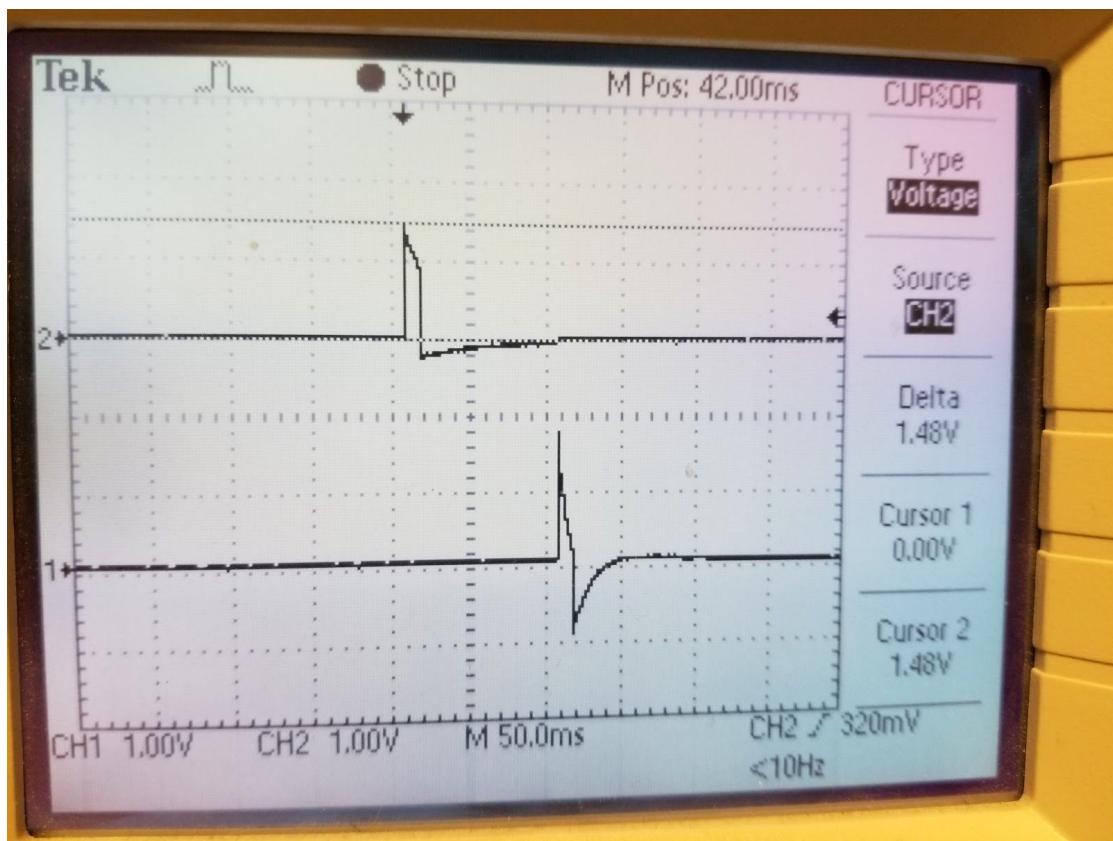
5.1. Test Case 1: Baseline

Pacemaker Interface

	AOO	VOO	AAI	VVI	D00	AOOR	VOOR	AAIR	VVIR	DOOR	DDDR	
Lower Rate Limit (ppm)	<input type="text" value="60"/>											
	50	65	80	95	110	125	140	155	170			
Upper Rate Limit (ppm)	<input type="text" value="150"/>											
	75	90	105	120	135	150	165	180	195			
Fixed AV Delay (ms)	<input type="text" value="100"/>											
	70	90	110	130	150	170	190	210	230	250	270	290
Atrial Amplitude (V)	<input type="text" value="1.5"/>											
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0		
Ventricular Amplitude (V)	<input type="text" value="2.0"/>											
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0		
Atrial Pulse Width (ms)	<input type="text" value="10"/>											
	1	2	3	4	5	6	7	8	9	10		
Ventricular Pulse Width (ms)	<input type="text" value="10"/>											
	1	2	3	4	5	6	7	8	9	10		
<input type="button" value="Submit"/>												







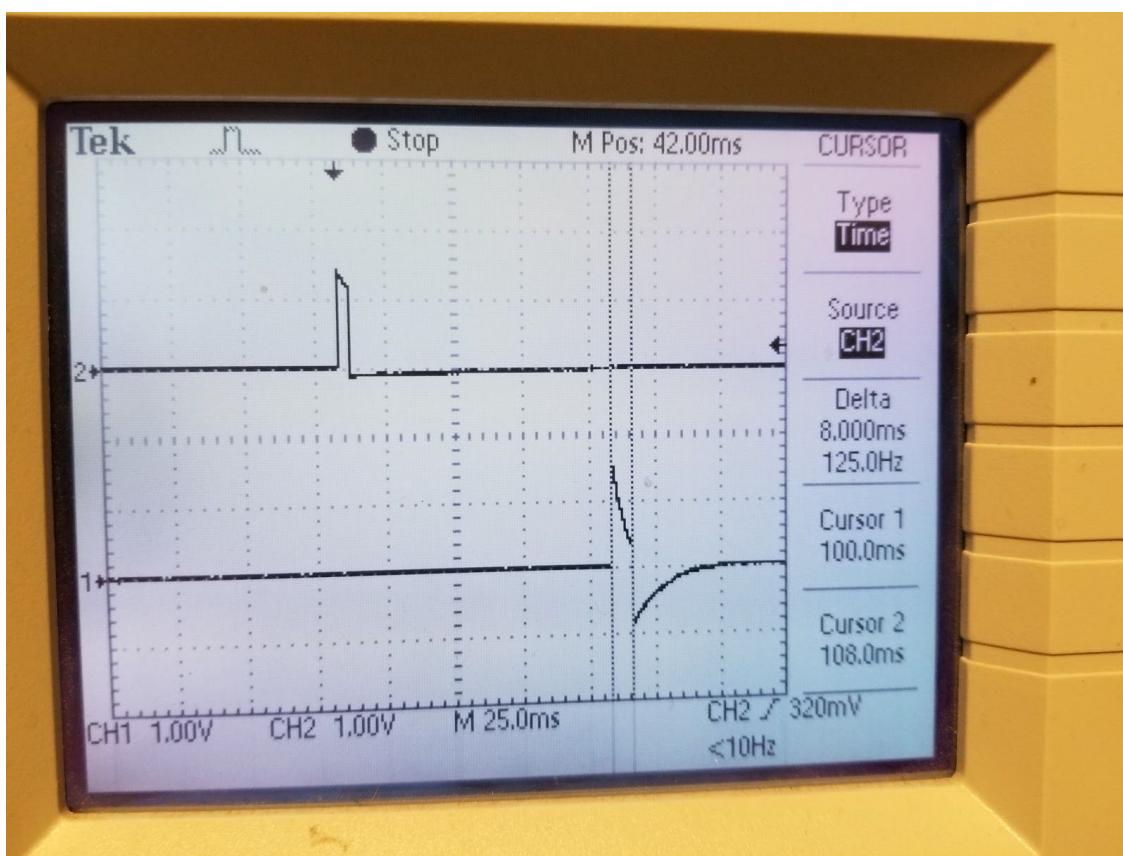
Atrium pulses are channel 2, ventricular pulses are channel 1.

Result: Pass. All timing measurements match input values. Amplitude of ventricle pulse deviated from input by 10% due to imperfect contacts.

5.2. Test Case 2: Varying Pulse Widths

Pacemaker Interface

	AOO	VOO	AAI	VVI	D00	AOOR	VOOR	AAIR	VVIR	DOOR	DDDR	
Lower Rate Limit (ppm)	<input type="range" value="60"/>											
	50	65	80	95	110	125	140	155	170			
Upper Rate Limit (ppm)	<input type="range" value="150"/>											
	75	90	105	120	135	150	165					
Fixed AV Delay (ms)	<input type="range" value="100"/>											
	70	90	110	130	150	170	190	210	230	250	270	290
Atrial Amplitude (V)	<input type="range" value="1.5"/>											
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0		
Ventricular Amplitude (V)	<input type="range" value="2.0"/>											
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0		
Atrial Pulse Width (ms)	<input type="range" value="4"/>											
	1	2	3	4	5	6	7	8	9	10		
Ventricular Pulse Width (ms)	<input type="range" value="8"/>											
	1	2	3	4	5	6	7	8	9	10		
<input type="button" value="Submit"/>												

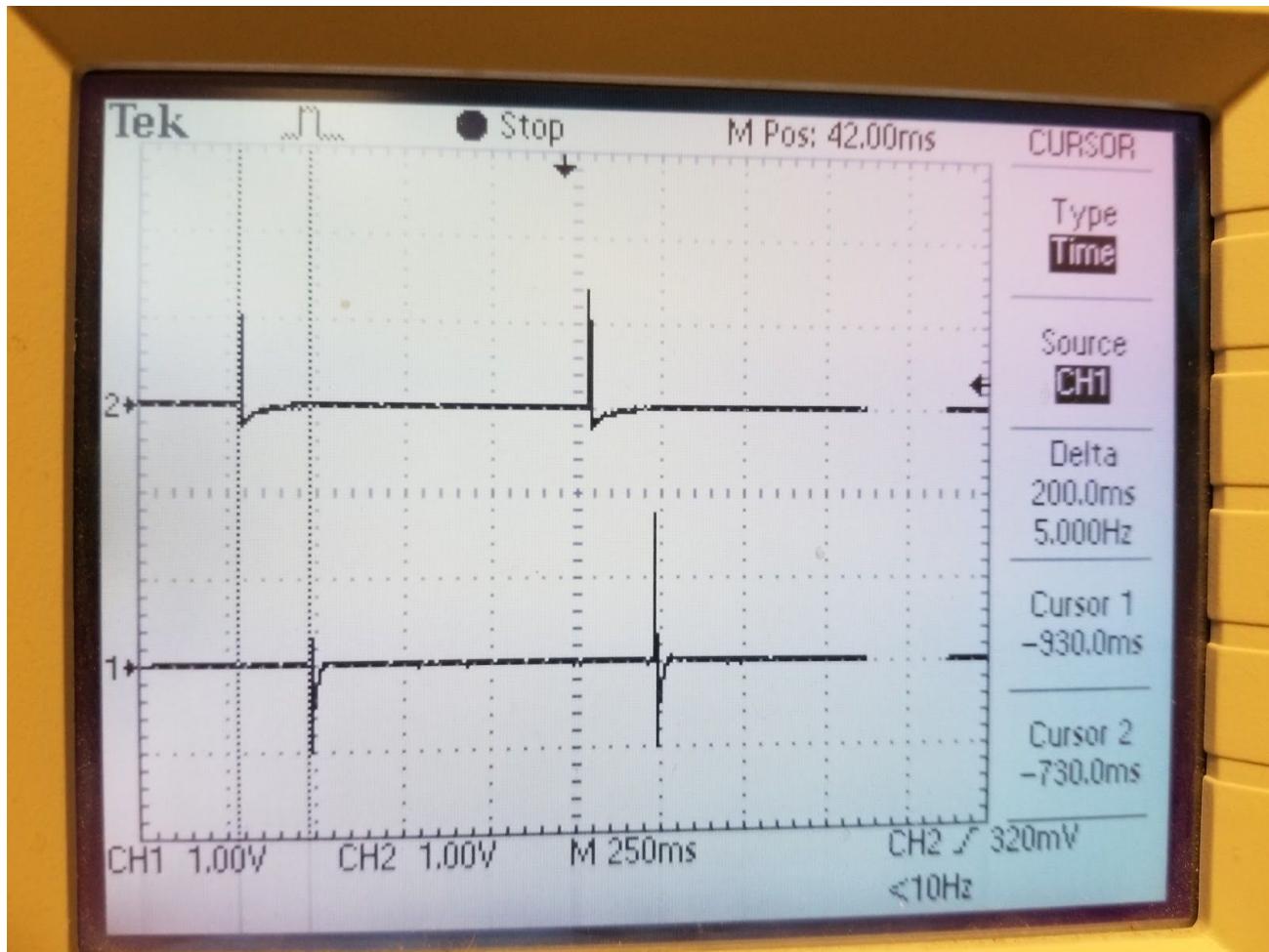


5.3. Test Case 3: Longer AV Delay

Pacemaker Interface

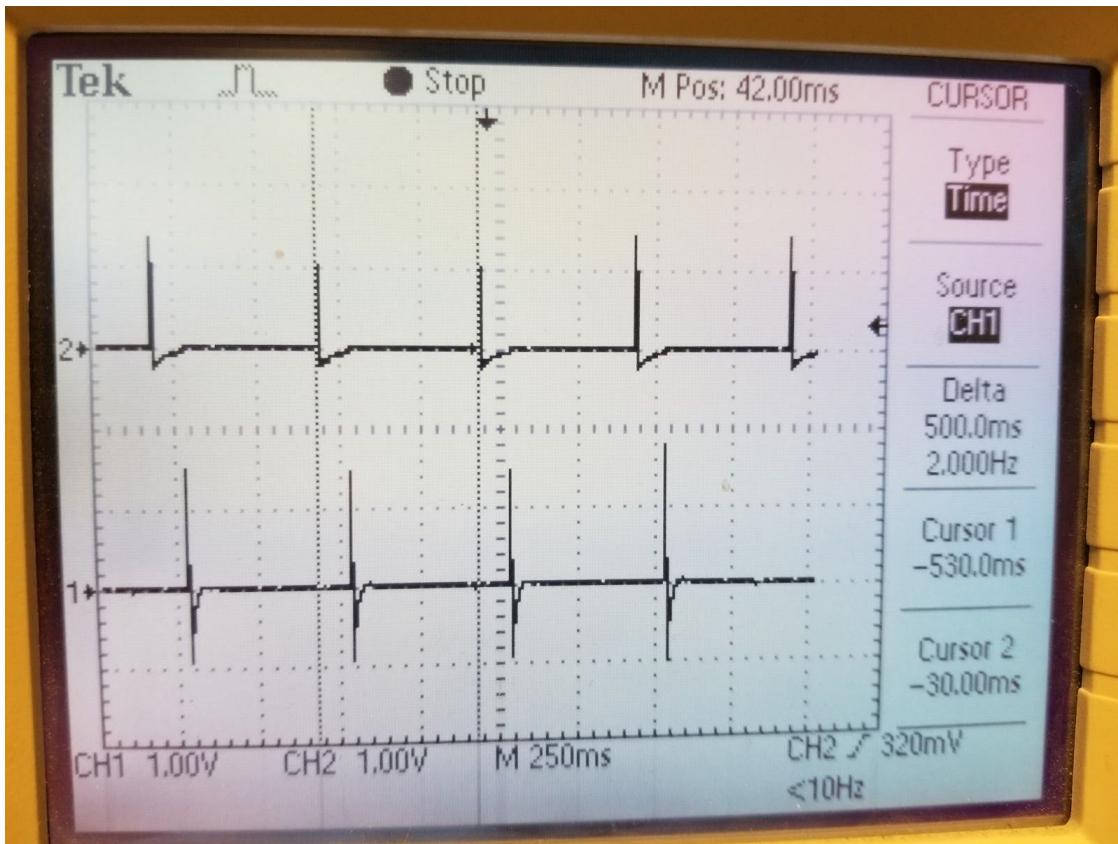
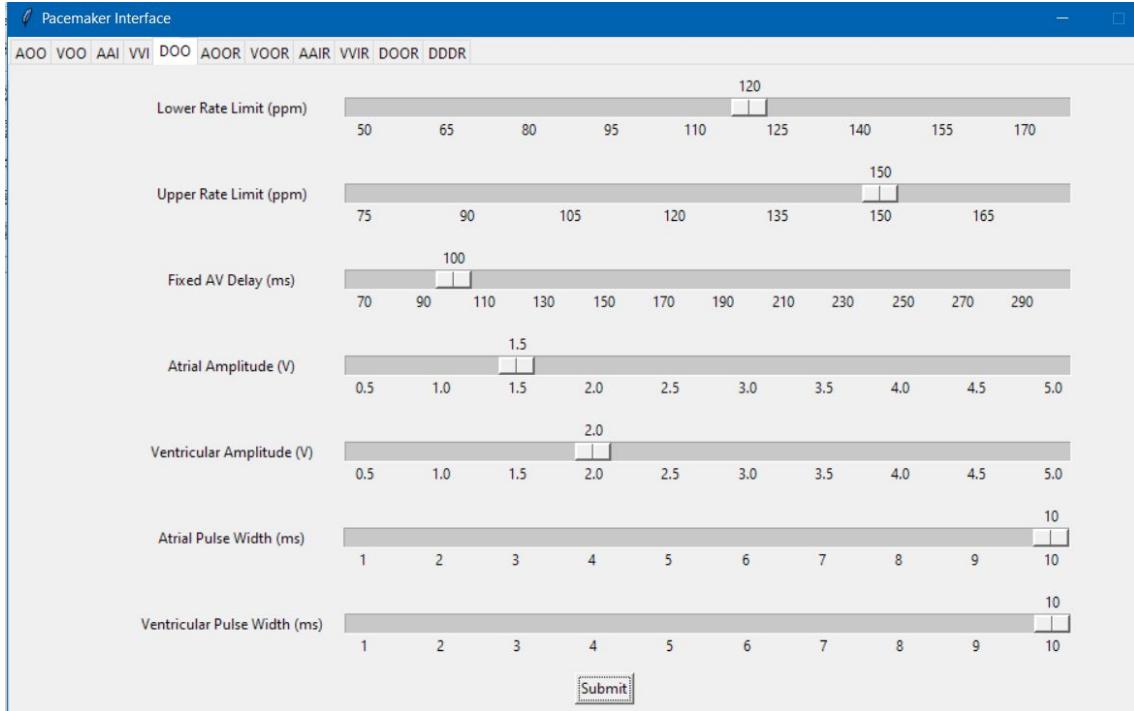
AOO VOO AAI VVI D00 AOOR VOOR AAIR VVIR DOOR DDDR

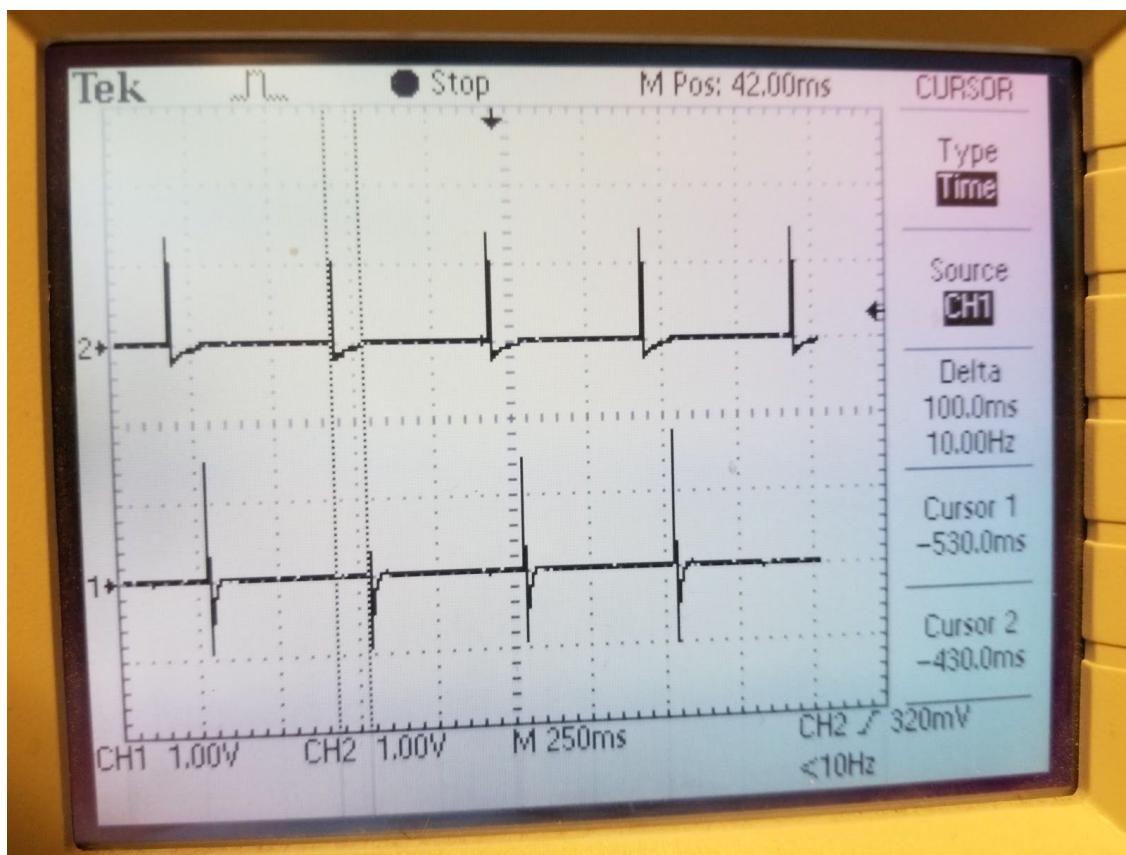
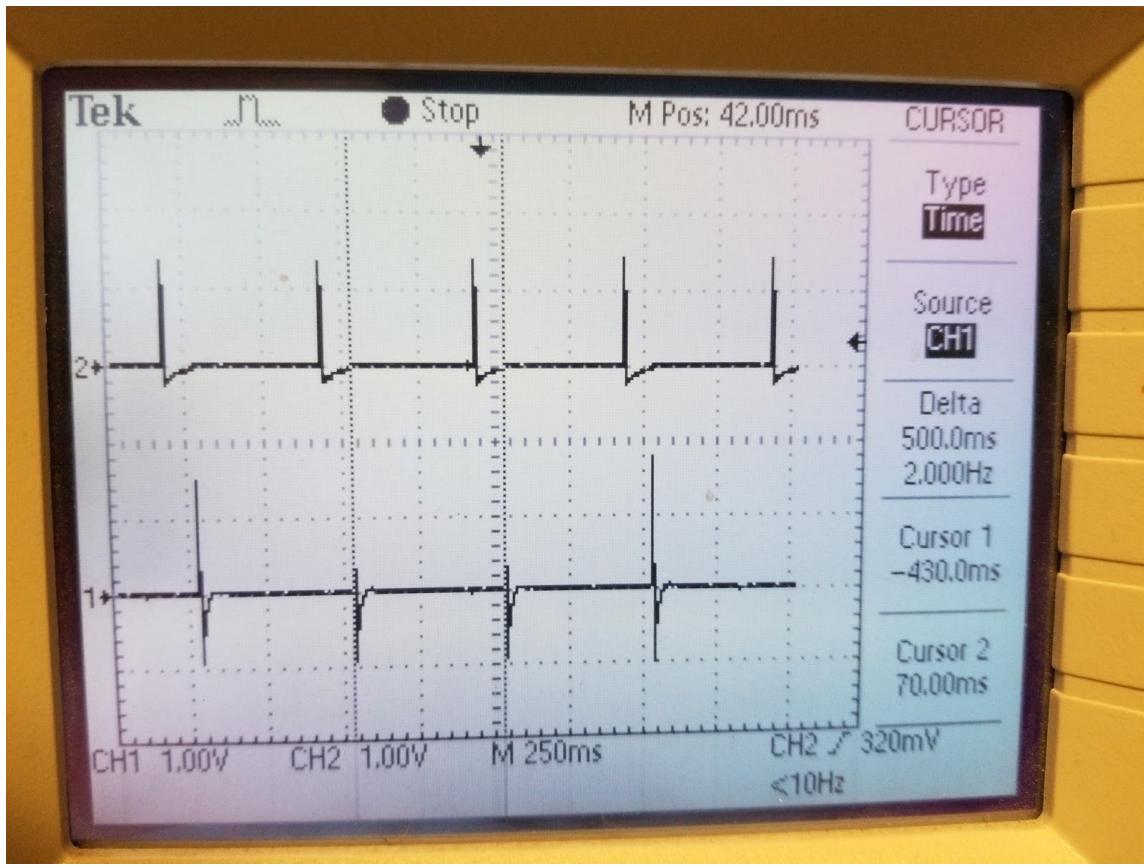
Lower Rate Limit (ppm)	60	50 65 80 95 110 125 140 155 170
Upper Rate Limit (ppm)	150	75 90 105 120 135 150 165
Fixed AV Delay (ms)	200	70 90 110 130 150 170 190 210 230 250 270 290
Atrial Amplitude (V)	1.5	0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Ventricular Amplitude (V)	2.0	0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0
Atrial Pulse Width (ms)	10	1 2 3 4 5 6 7 8 9 10
Ventricular Pulse Width (ms)	10	1 2 3 4 5 6 7 8 9 10
<input type="button" value="Submit"/>		



Result: Pass. AV delay correctly adjusted to 200ms input.

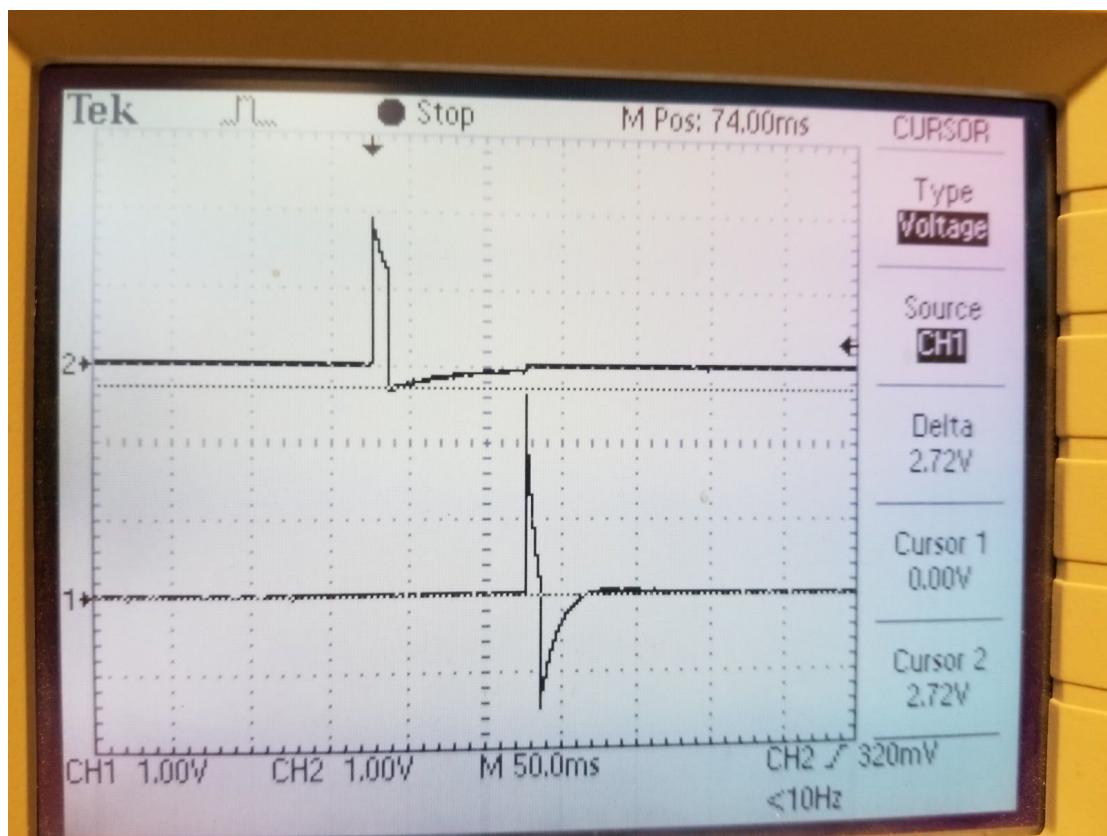
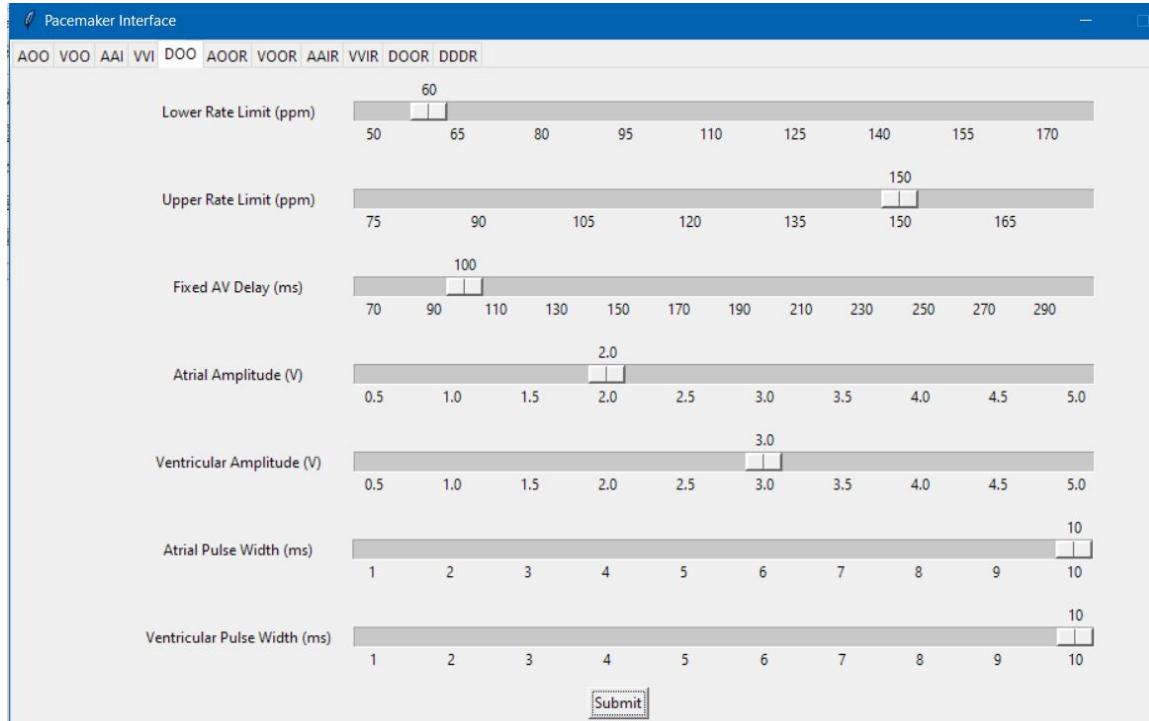
5.4. Test Case 4: Higher LRL

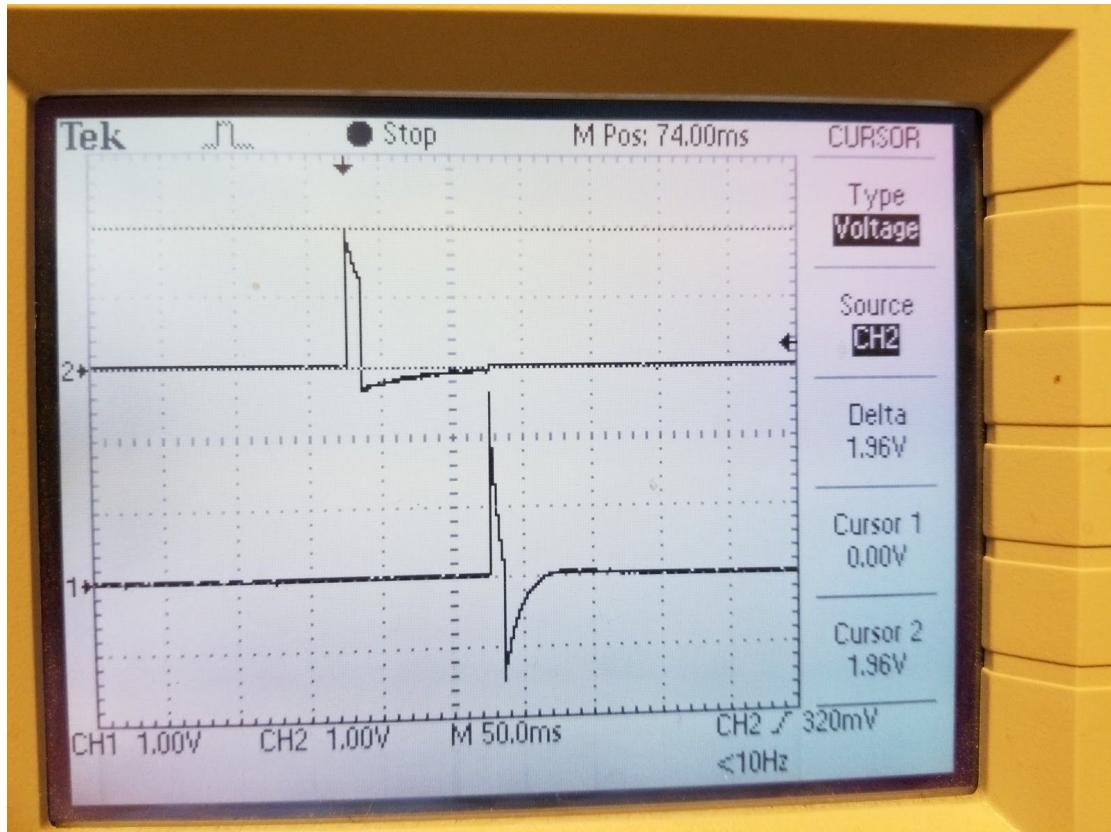




Result: Pass. Period correctly adjusted to twice per second while maintaining AV delay.

5.5. Test Case 5: Higher Amplitudes





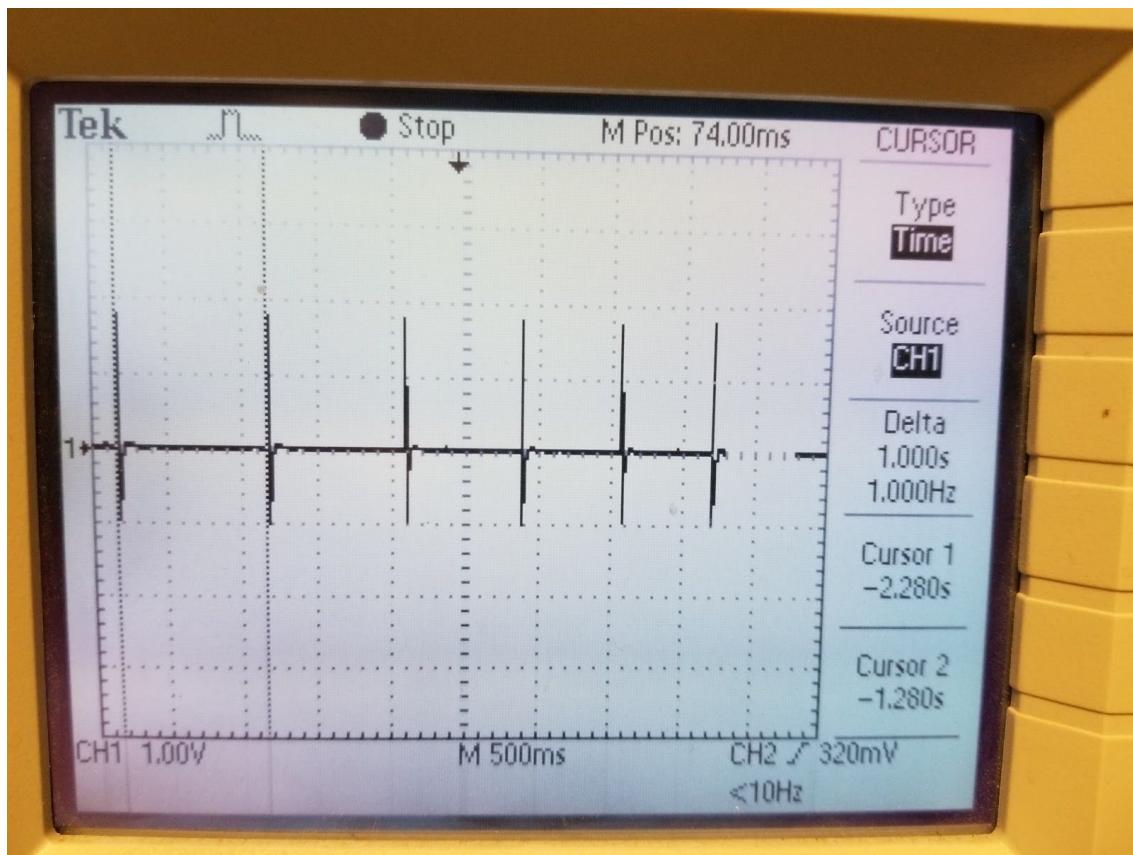
Result: Pass. Amplitudes increase by ~1 volt for each pulse. Ventricle deviates from nominal by ~10% due to imperfect contacts.

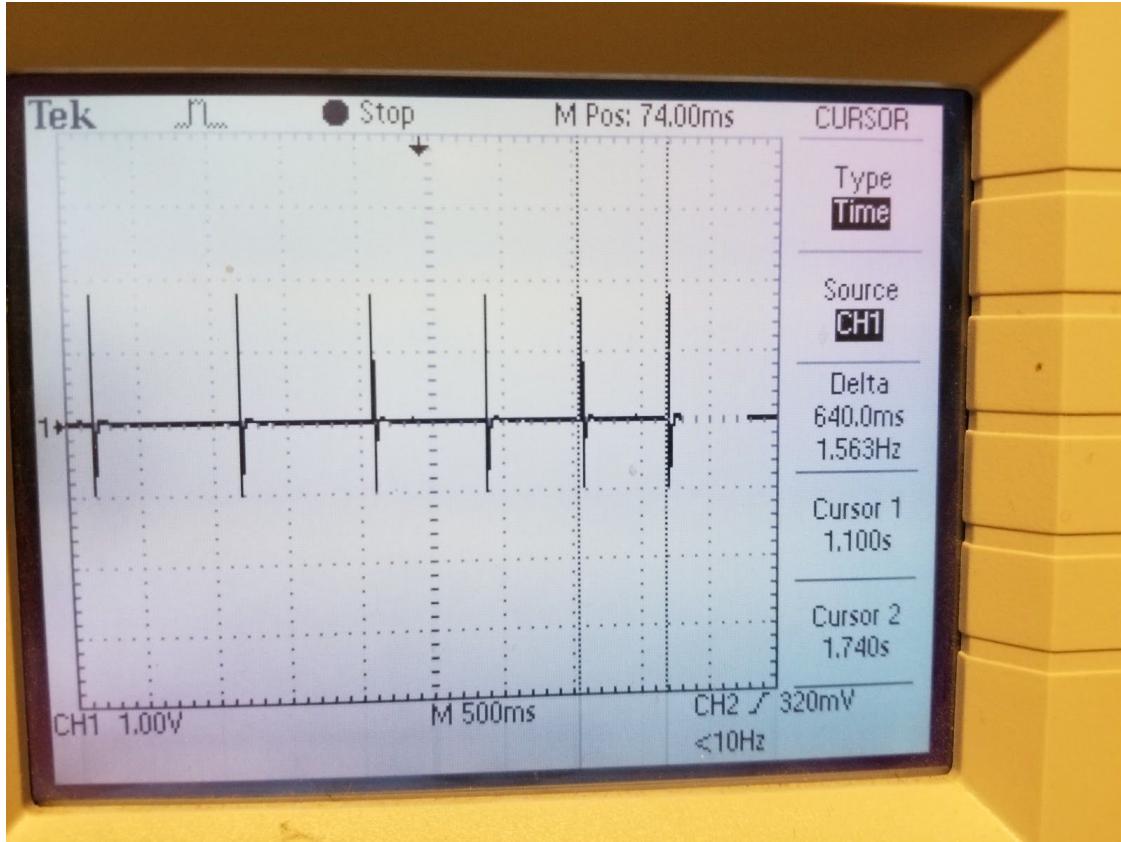
6. AOOR Testing

6.1. Test Case 1: Rate Ramp Up

Pacemaker Interface

	AOO	VOO	AAI	VVI	DIO	AOOR	VOOR	AAIR	VVIR	DOOR	DDDR																
Lower Rate Limit (ppm)	60						Atrial Pulse Width (ms) 10																				
	50	65	80	95	110	125	140	155	170	1	2	3	4	5	6	7	8	9	10								
Upper Rate Limit (ppm)	150						Reaction Time (s) 4																				
	75	90	105	120	135	150	165	1	3	5	7	9	11	13	15	17	19	21	23	25	27	29					
Max Sensor Rate (ppm)	120						Recovery Time(s) 10																				
	50	60	70	80	90	100	110	120	130	140	150	160	170	5	7	9	11	13	15	17	19	21	23	25	27	29	
Atrial Amplitude (V)	2.0						Response Factor (Slow-Fast) 8																				
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	
Activity Threshold (Low-High)	1																										
	1	2	3	4																							
<input type="button" value="Submit"/>																											





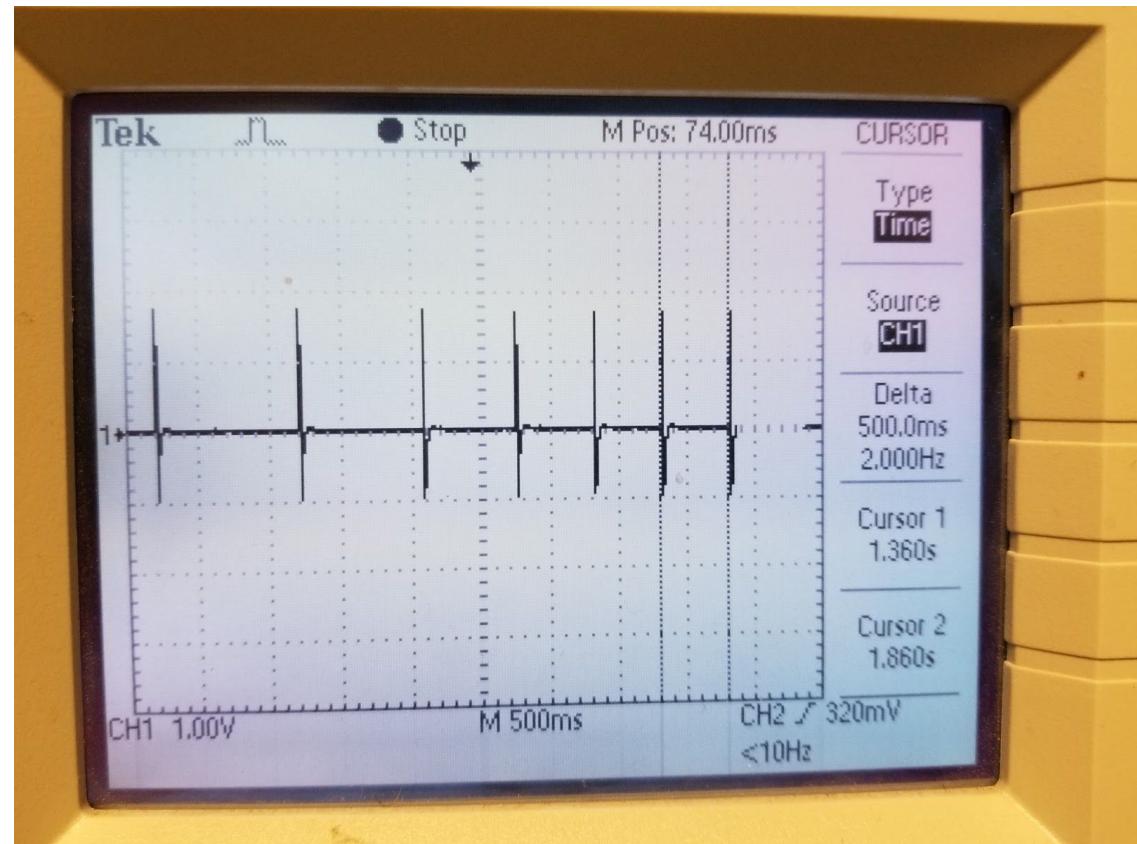
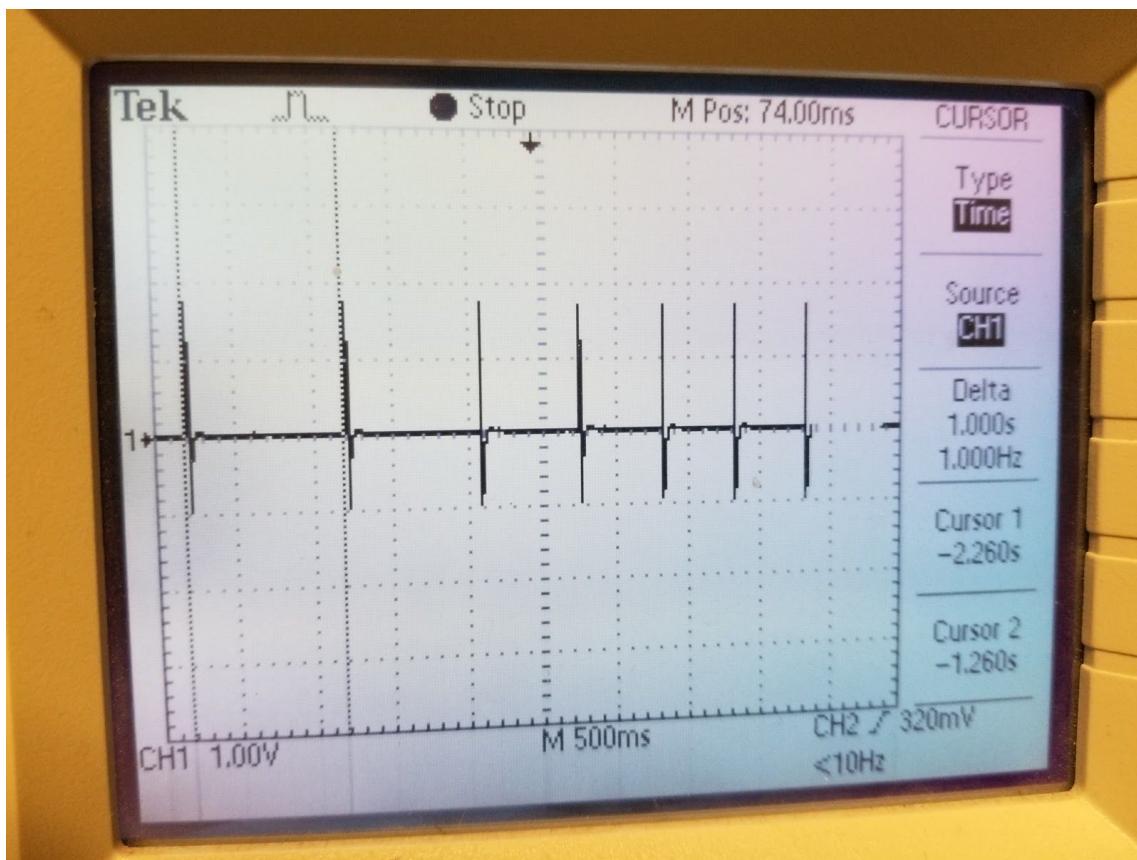
Result: Pass. Period gradually tightens over time. Note that the rate does not reach MSR during the time window for the baseline test.

6.2. Test Case 2: Faster Ramp Up from Higher Response Factor

The figure shows a 'Pacemaker Interface' software window. It contains several configuration parameters with their current values:

- Lower Rate Limit (ppm): 60
- Upper Rate Limit (ppm): 150
- Max Sensor Rate (ppm): 120
- Atrial Amplitude (V): 2.0
- Atrial Pulse Width (ms): 10
- Reaction Time (s): 4
- Recovery Time(s): 10
- Response Factor (Slow-Fast): 16
- Activity Threshold (Low-High): 1

At the bottom right is a 'Submit' button.



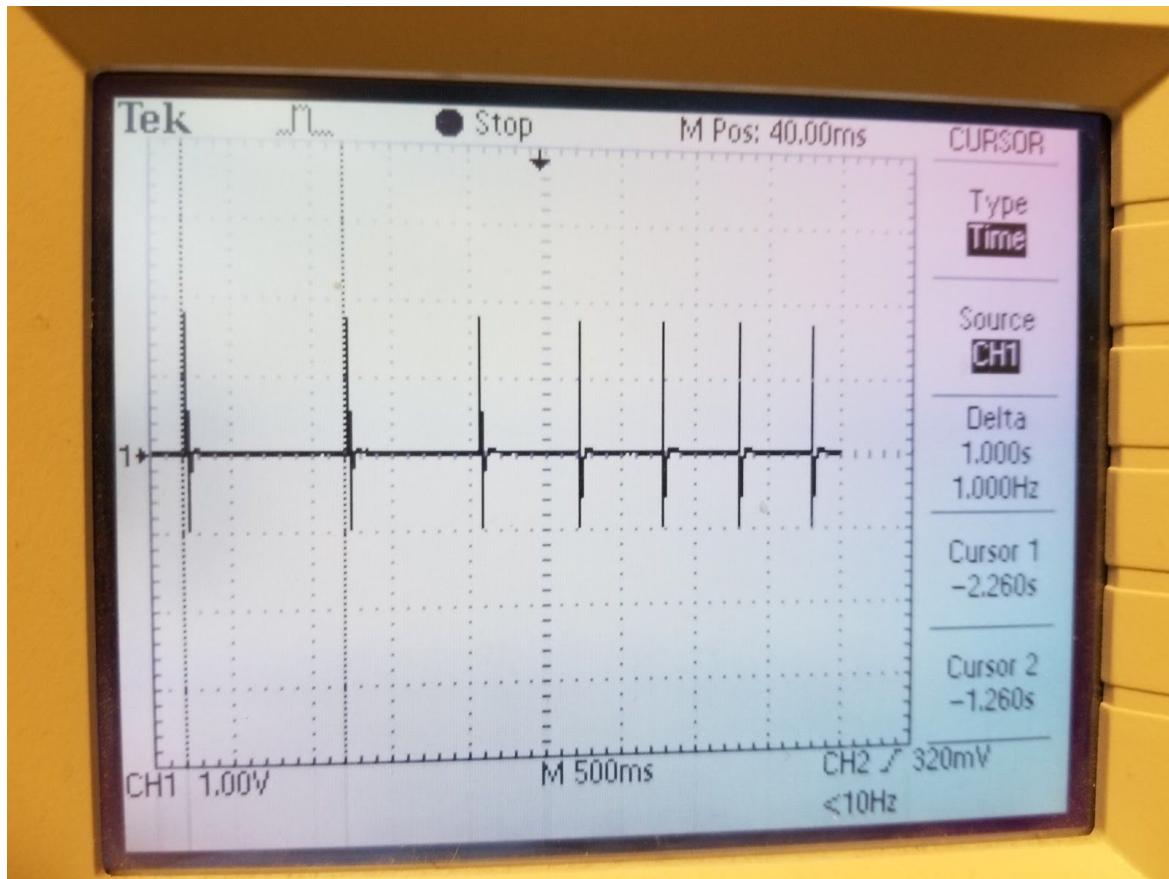
Results: Pass. The rate increases gradually but at a faster rate, and reaches MSR within the same time window as the baseline test.

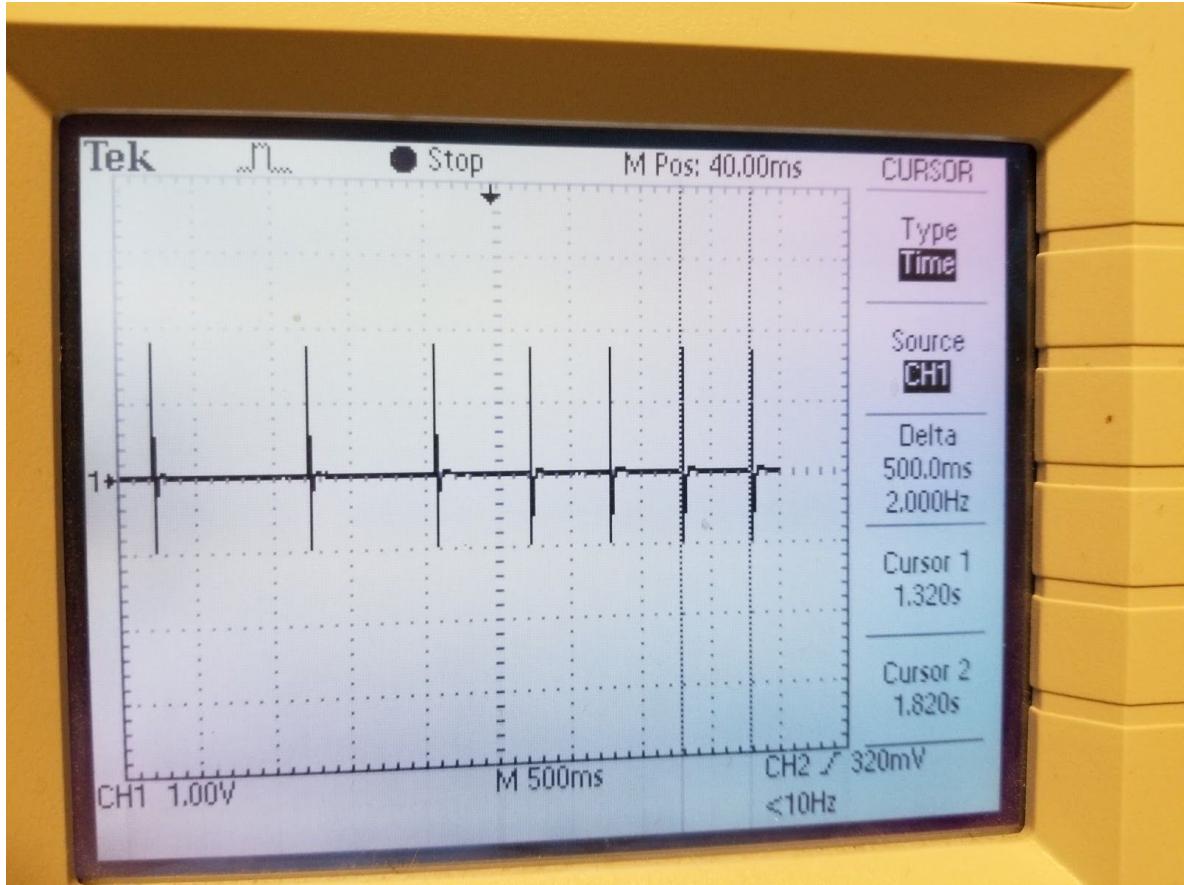
6.3. Test Case 3: Faster Ramp Up from Lower Reaction Time

Pacemaker Interface

AOO VOO AAI VVI DDO AOOR VOOR AAIR VVIR DOOR DDDR

Lower Rate Limit (ppm)	60	Atrial Pulse Width (ms)	10
	50 65 80 95 110 125 140 155 170	1 2 3 4 5 6 7 8 9 10	
Upper Rate Limit (ppm)	150	Reaction Time (s)	2
	75 90 105 120 135 150 165	1 3 5 7 9 11 13 15 17 19 21 23 25 27 29	
Max Sensor Rate (ppm)	120	Recovery Time(s)	10
	50 60 70 80 90 100 110 120 130 140 150 160 170	5 7 9 11 13 15 17 19 21 23 25 27 29	
Atrial Amplitude (V)	2.0	Response Factor (Slow-Fast)	8
	0.5 1.0 1.5 2.0 2.5 3.0 3.5 4.0 4.5 5.0	1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16	
Activity Threshold (Low-High)	1		
	1 2 3 4		
<input type="button" value="Submit"/>			





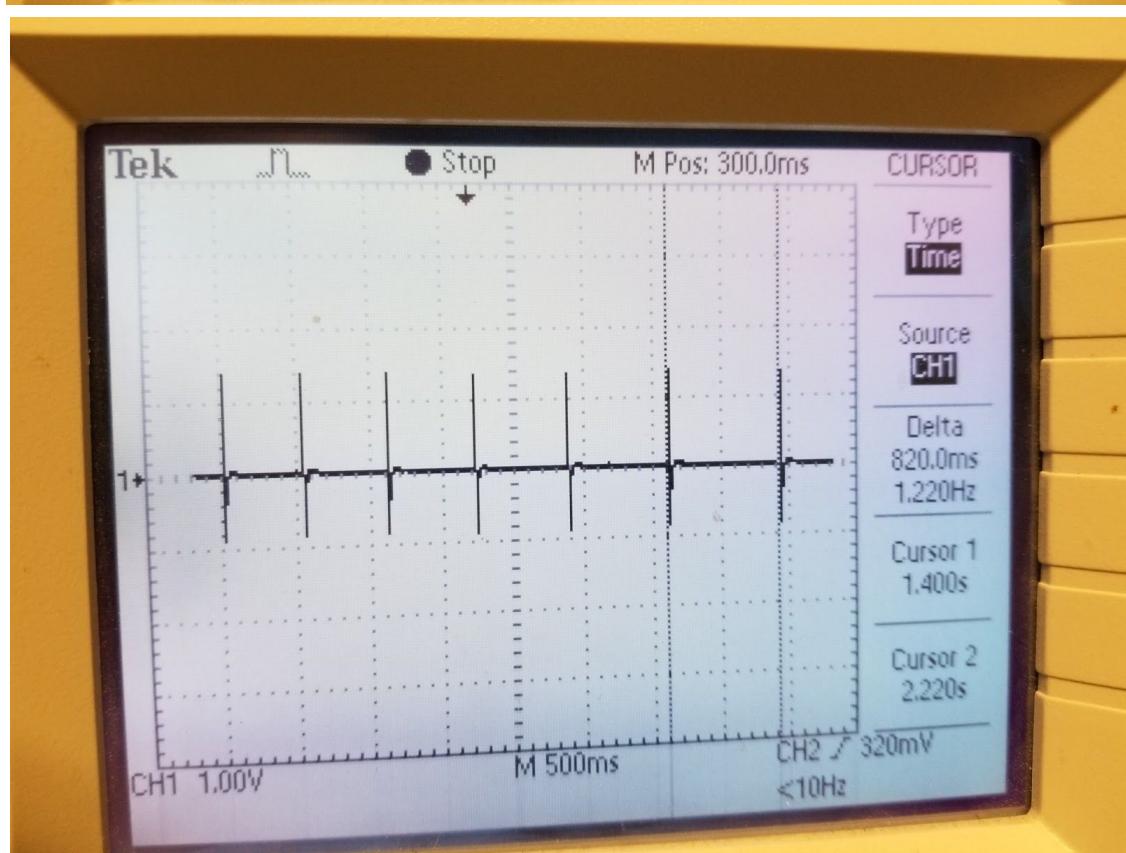
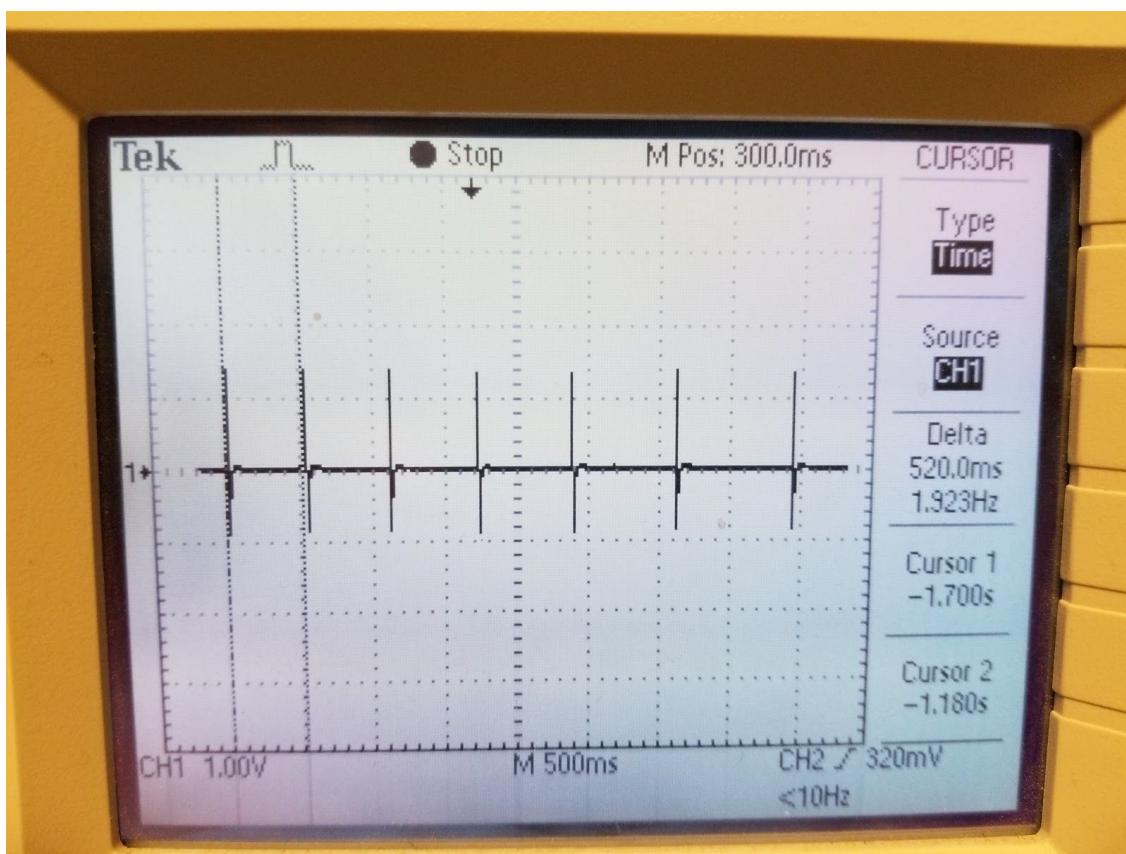
Result: Pass. The rate increases gradually but at a faster rate, and reaches MSR within the same time window as the baseline test.

6.4. Test Case 4: Ramp Down

Pacemaker Interface

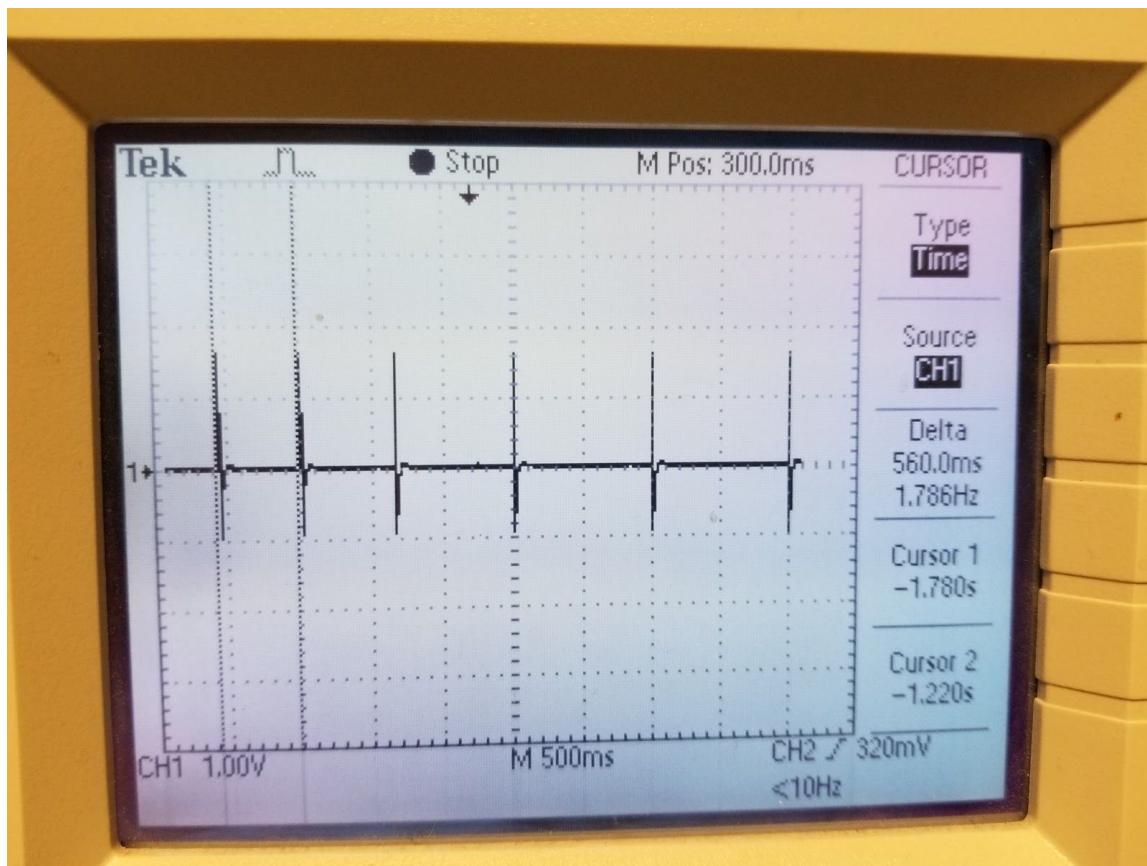
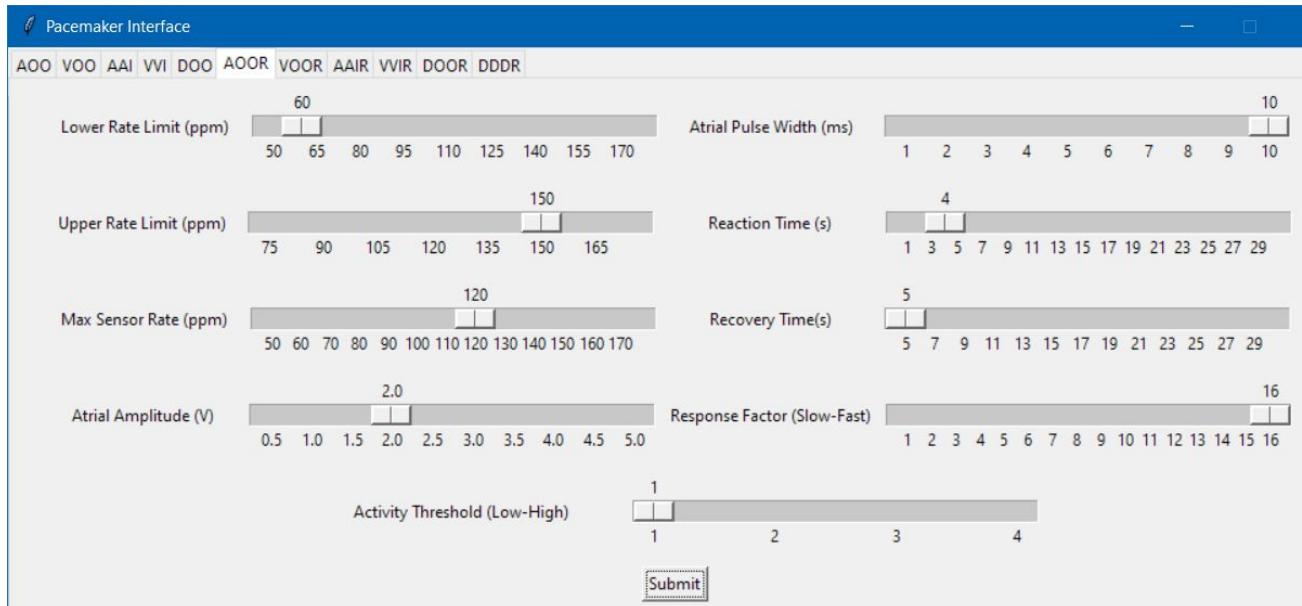
Mode	Value
AAI	
VVI	
VOO	
AOO	
VOOR	
AAIR	
VVIR	
DOOR	
DDDR	

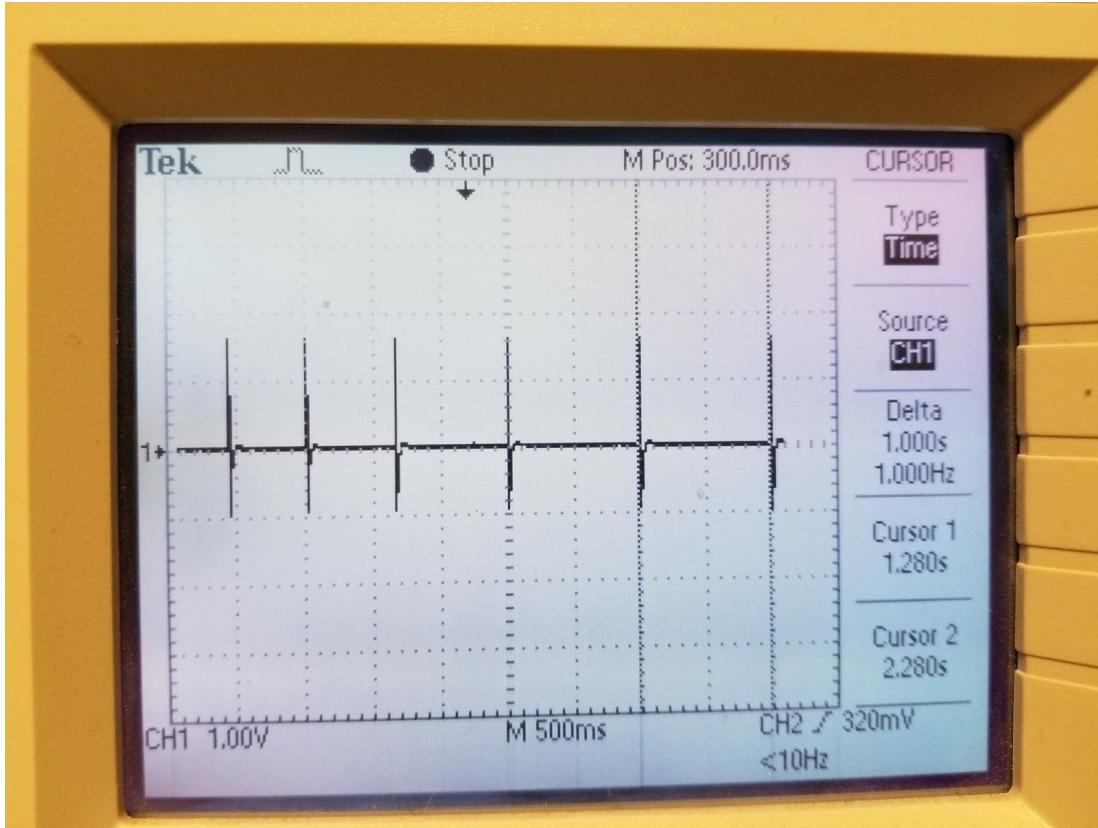
Lower Rate Limit (ppm)	60	Atrial Pulse Width (ms)	10
Upper Rate Limit (ppm)	150	Reaction Time (s)	4
Max Sensor Rate (ppm)	120	Recovery Time(s)	5
Atrial Amplitude (V)	2.0	Response Factor (Slow-Fast)	8
Activity Threshold (Low-High)	1		



Result: Pass. Rate gradually decreases over time.

6.5. Test Case 5: Faster Ramp Down with Higher Response Factor





Result: Pass. Rate gradually decreases but at a faster rate, and is able to reach LRL within the same time window as test case 4.

6.6. Test Case 6: Higher MSR

Pacemaker Interface

Mode	AOO	VVO	AAI	VVI	DIO	AOOR	VOOR	AAIR	VVIR	DOOR	DDDR
Lower Rate Limit (ppm)	60										
	50	65	80	95	110	125	140	155	170		
Atrial Pulse Width (ms)										10	
	1	2	3	4	5	6	7	8	9	10	
Upper Rate Limit (ppm)										4	
	75	90	105	120	135	150	165				
Reaction Time (s)											
	1	3	5	7	9	11	13	15	17	19	21
Max Sensor Rate (ppm)										5	
	50	60	70	80	90	100	110	120	130	140	150
Recovery Time(s)											
	5	7	9	11	13	15	17	19	21	23	25
Atrial Amplitude (V)										16	
	0.5	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	
Response Factor (Slow-Fast)											
	1	2	3	4	5	6	7	8	9	10	11
Activity Threshold (Low-High)											
	1	2	3	4							
<input type="button" value="Submit"/>											



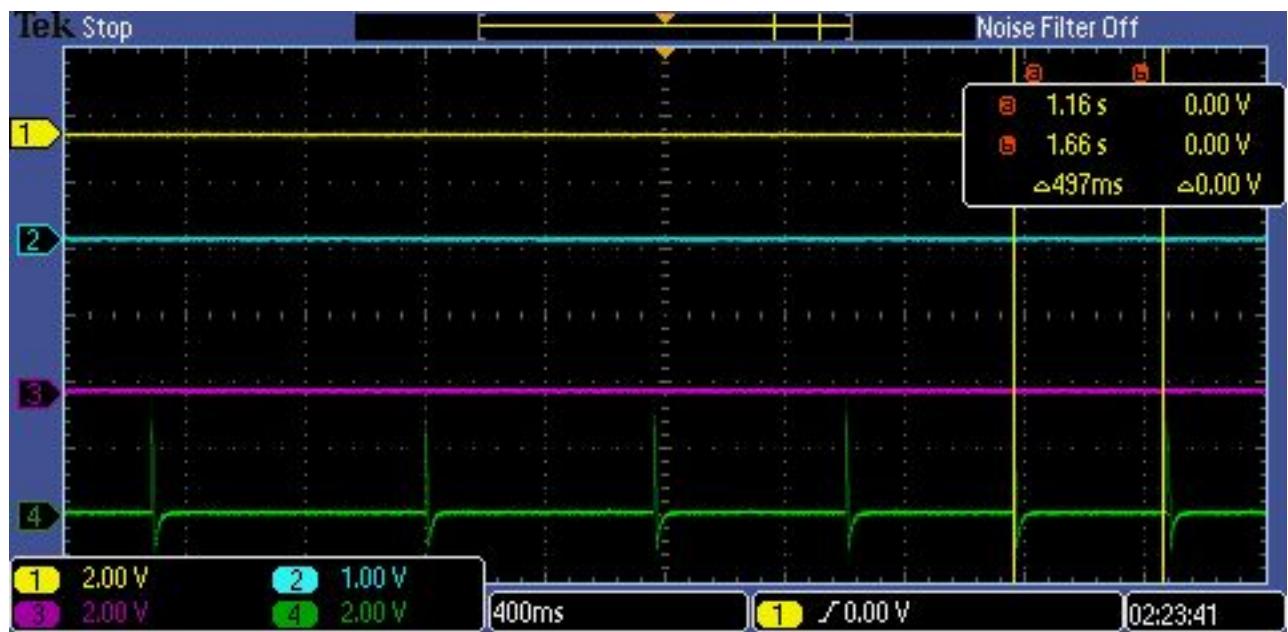
Result: Pass. Rate increases to a higher MSR period of 375ms (within the resolution of the scope).

7. VOOR Testing

VOOR testing was limited but follows the exact same logic as the AOOR mode which was tested more rigorously. Given the limited testing ability it was assumed that the AOOR functionality carried over to VOOR.

7.1. Test Case 1:

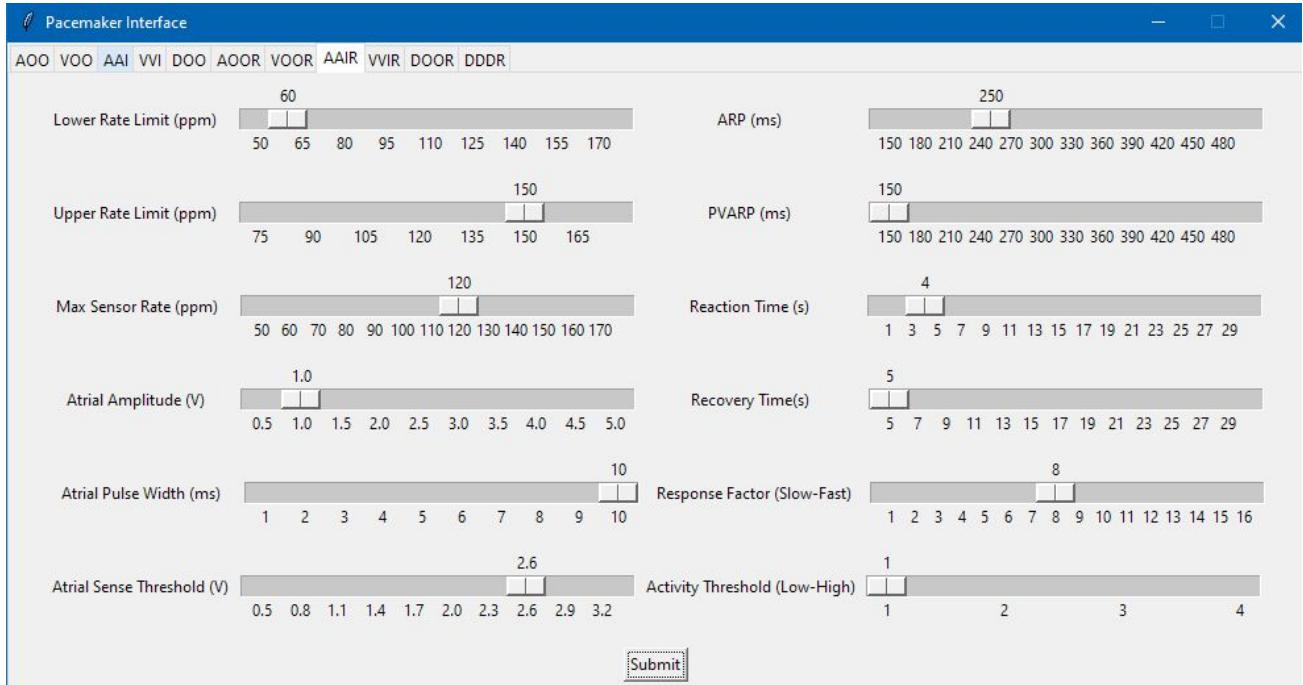




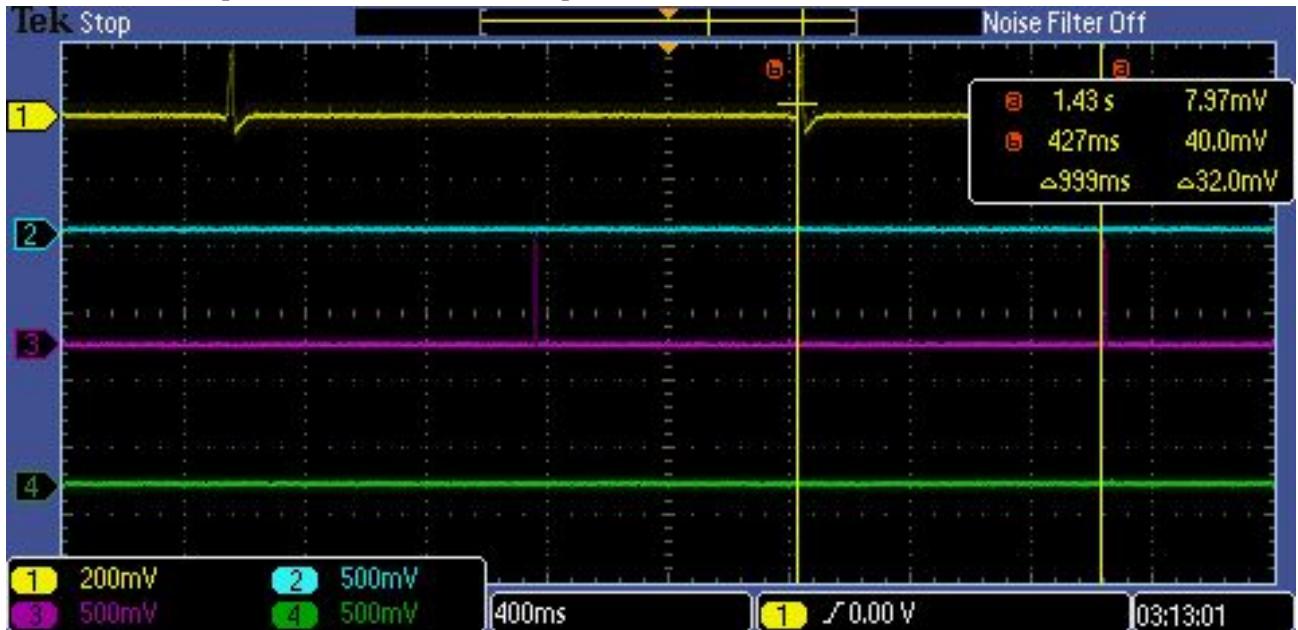
Result: Pass. Rate increased gradually to MSR.

8. AAIR Testing

8.1. Test Case 1: Inhibiting a Pace

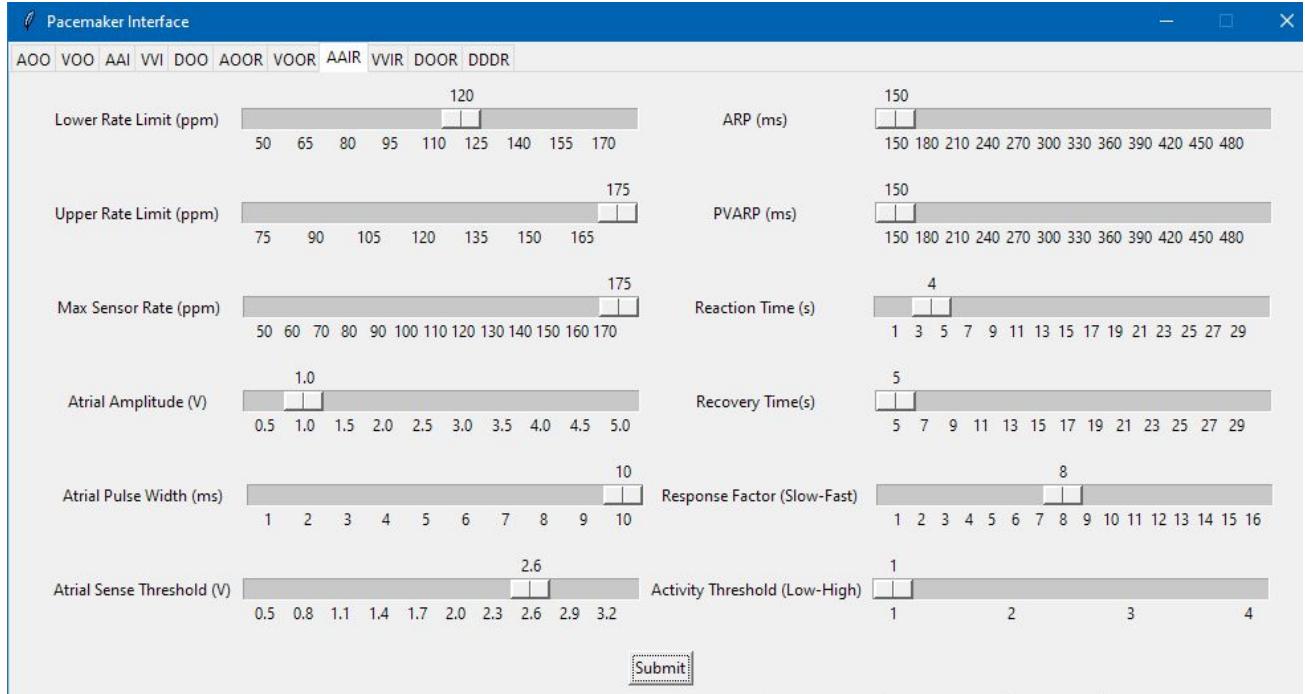


The labview atrial pulse was set to a rate of 32bpm.

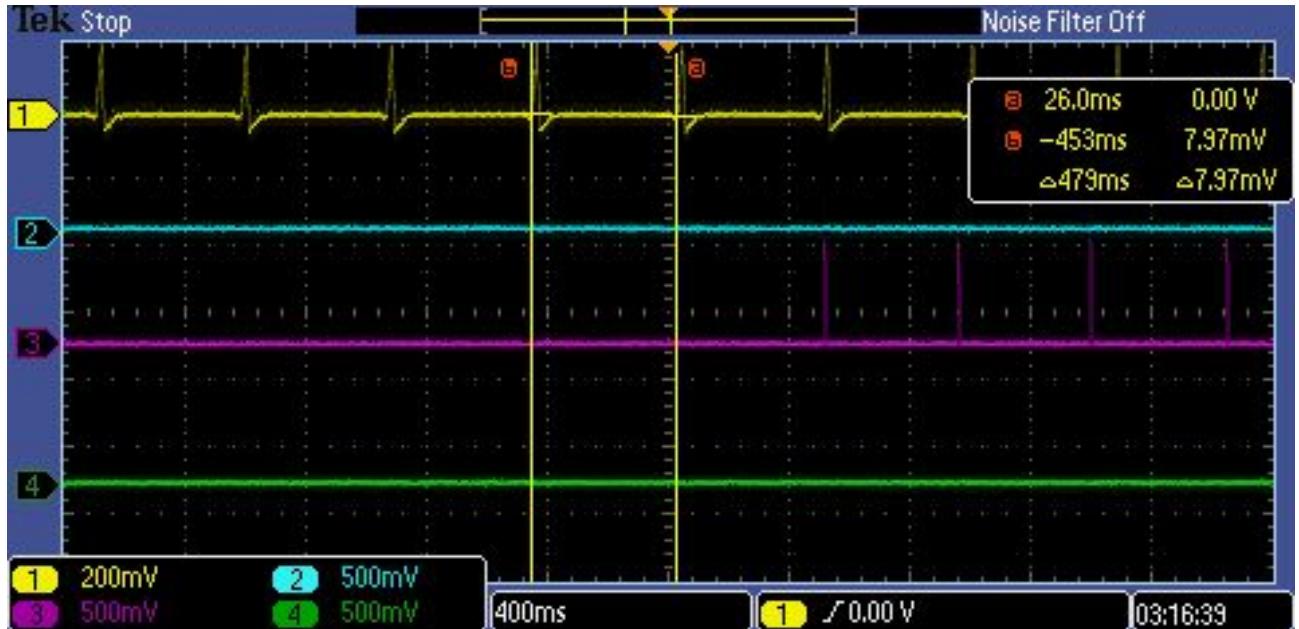


Result: Pass. The natural pulse (yellow) causes the artificial pacing (purple) to delay by one period following a natural pulse.

8.2. Test Case 2: MSR Higher than Natural Pacing Rate



The labview atrial pulse was set to a rate of 125bpm, between LRL and MSR.

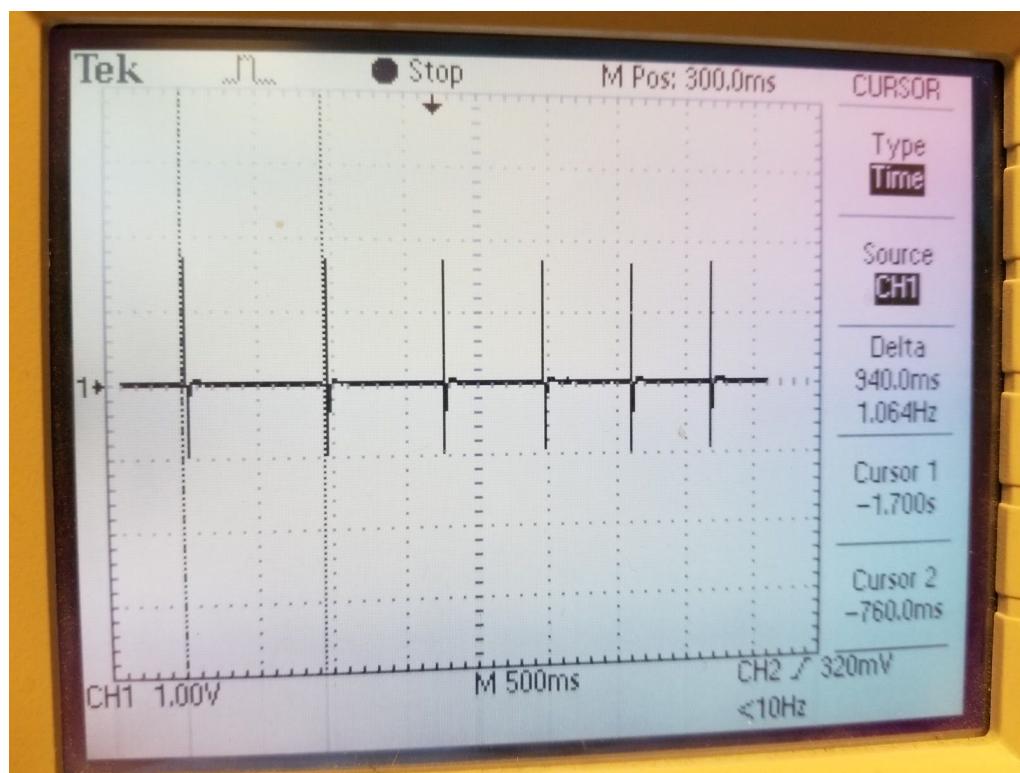
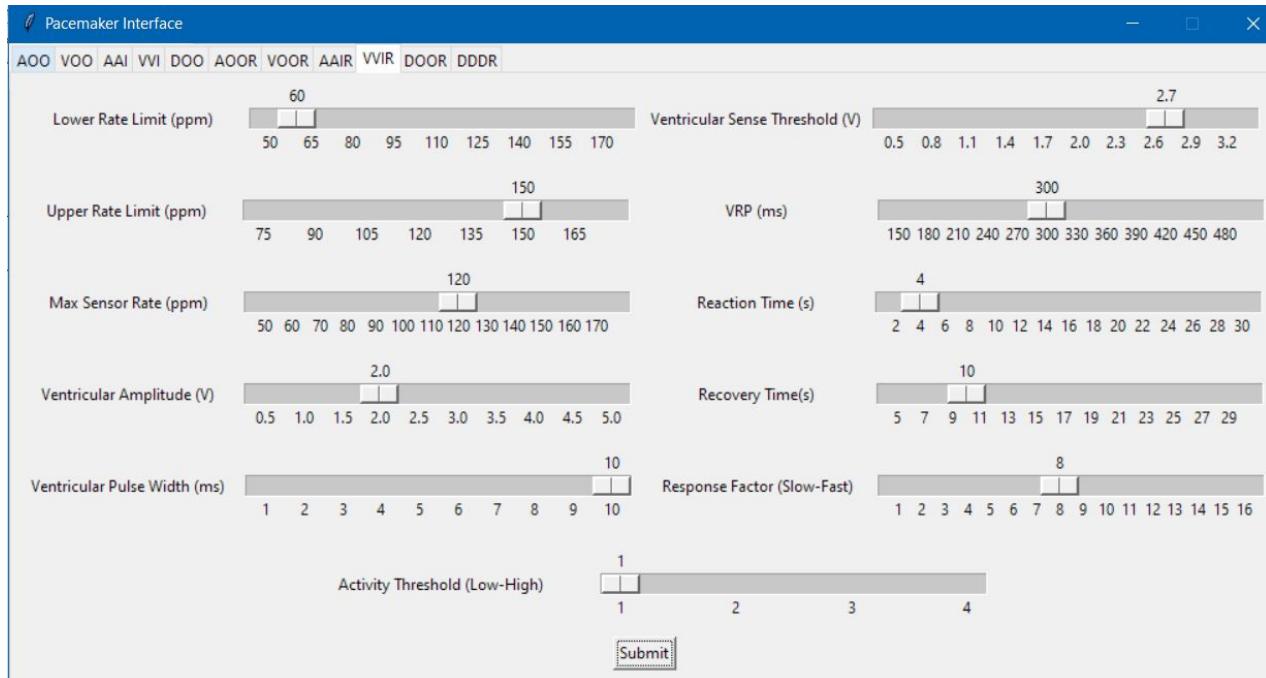


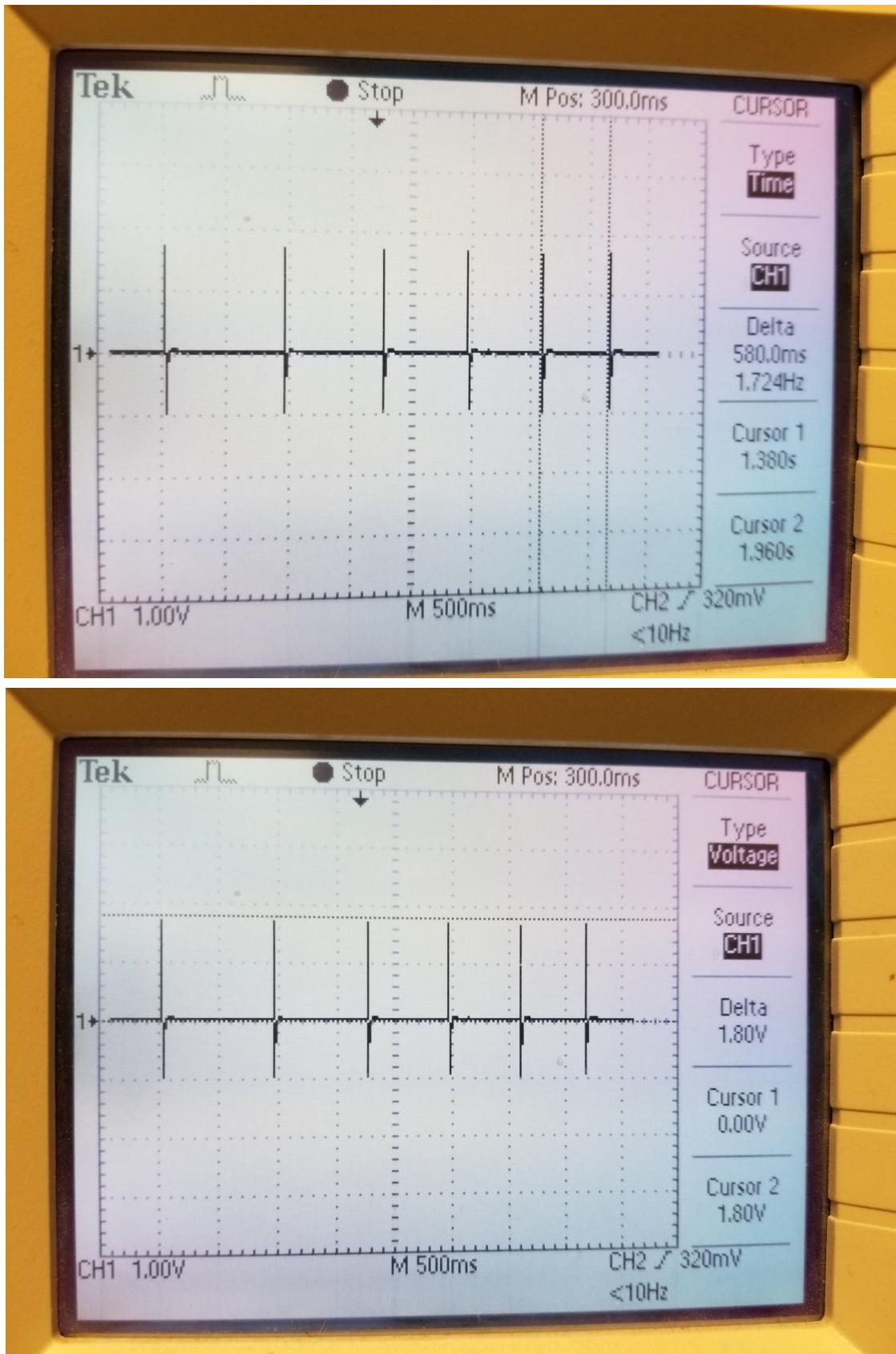
Result: Pass. Initially no pacing occurred since the pacemaker was running at LRL less than the natural rate. Then after shaking the pacemaker, the rate rose above the natural rate of 125bpm and began pacing.

9. VVIR Testing

Due to limited availability of the labview testing equipment, responses to natural pacing could not be tested for this mode.

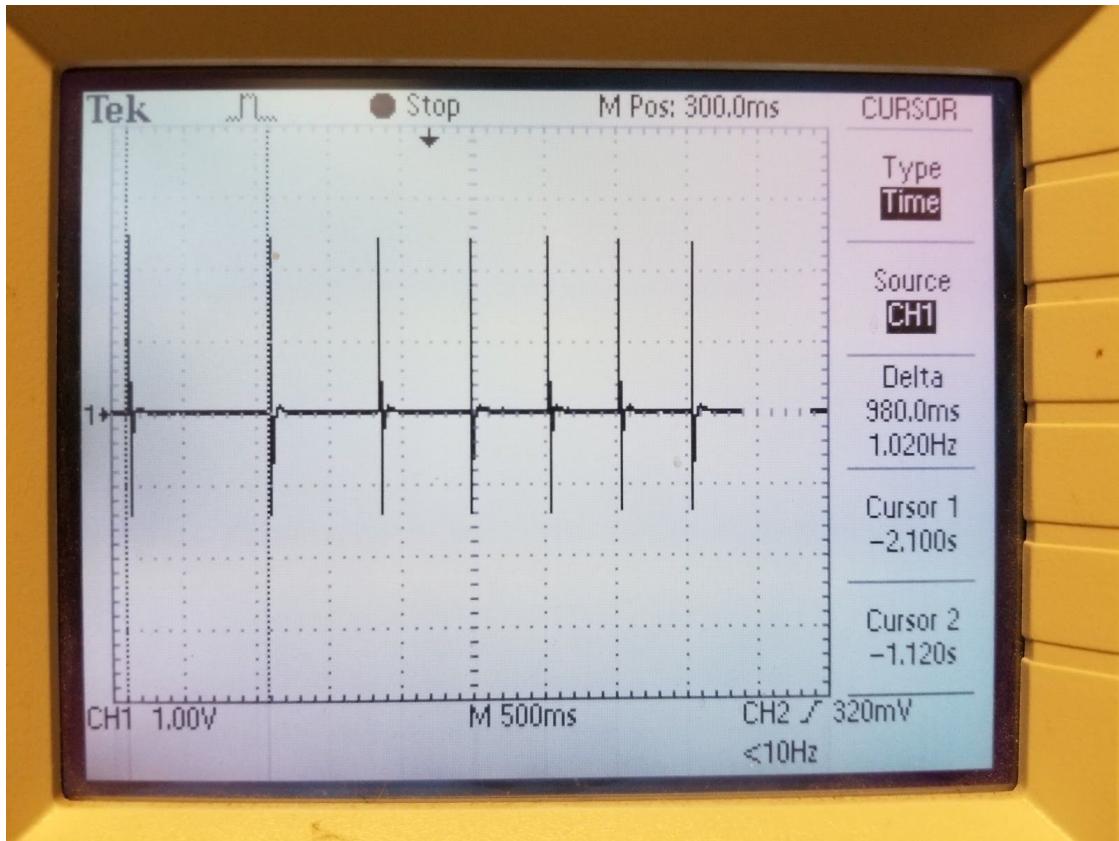
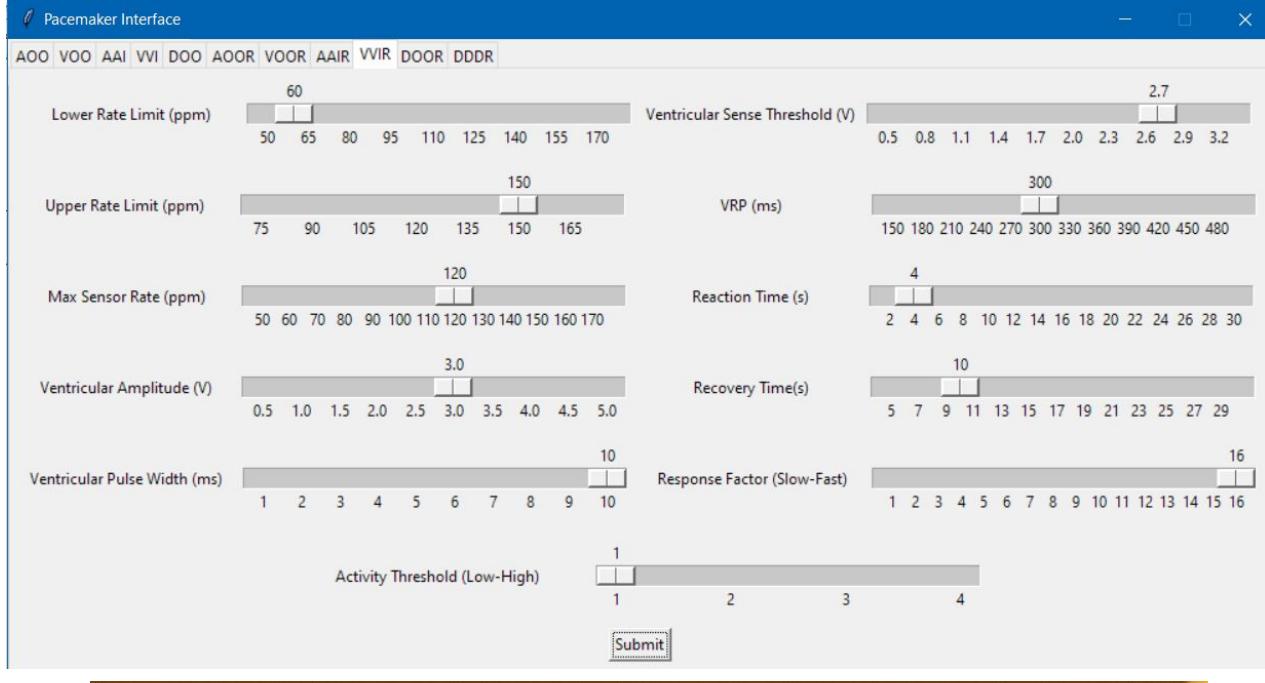
9.1. Test Case 1: Rate Ramp Up

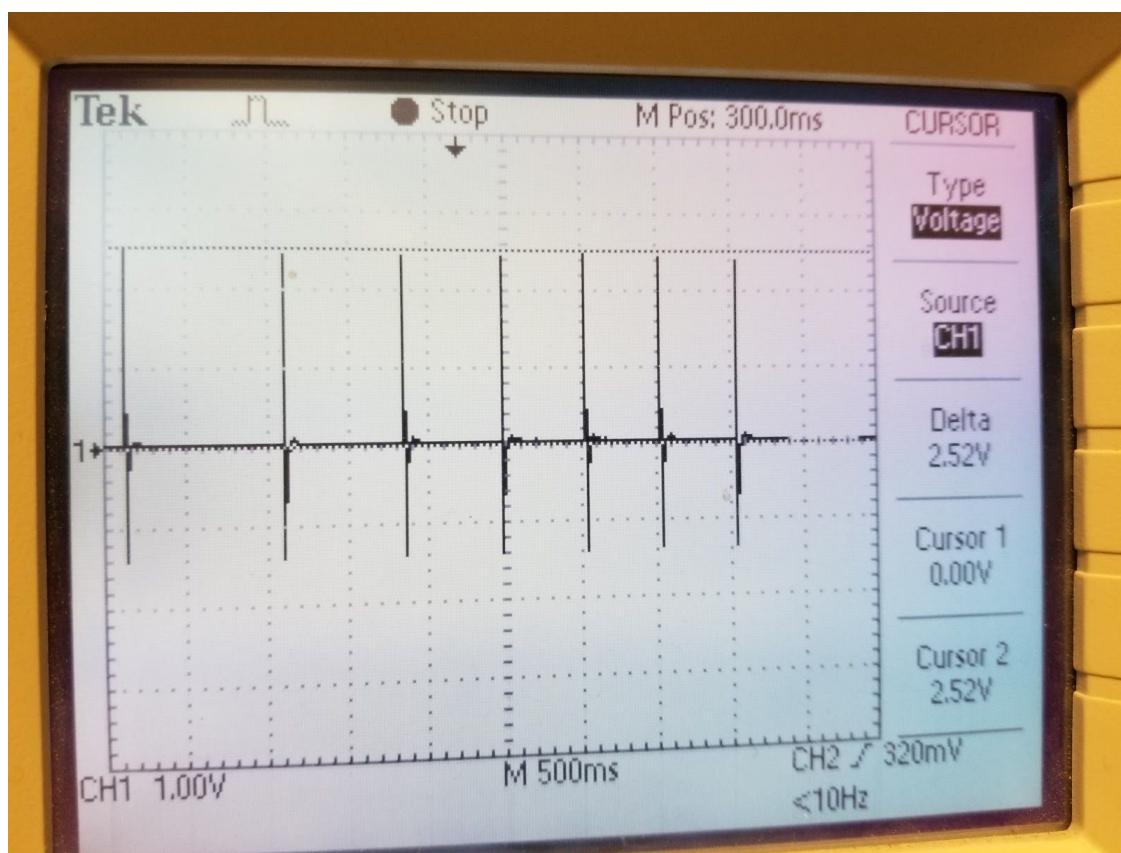
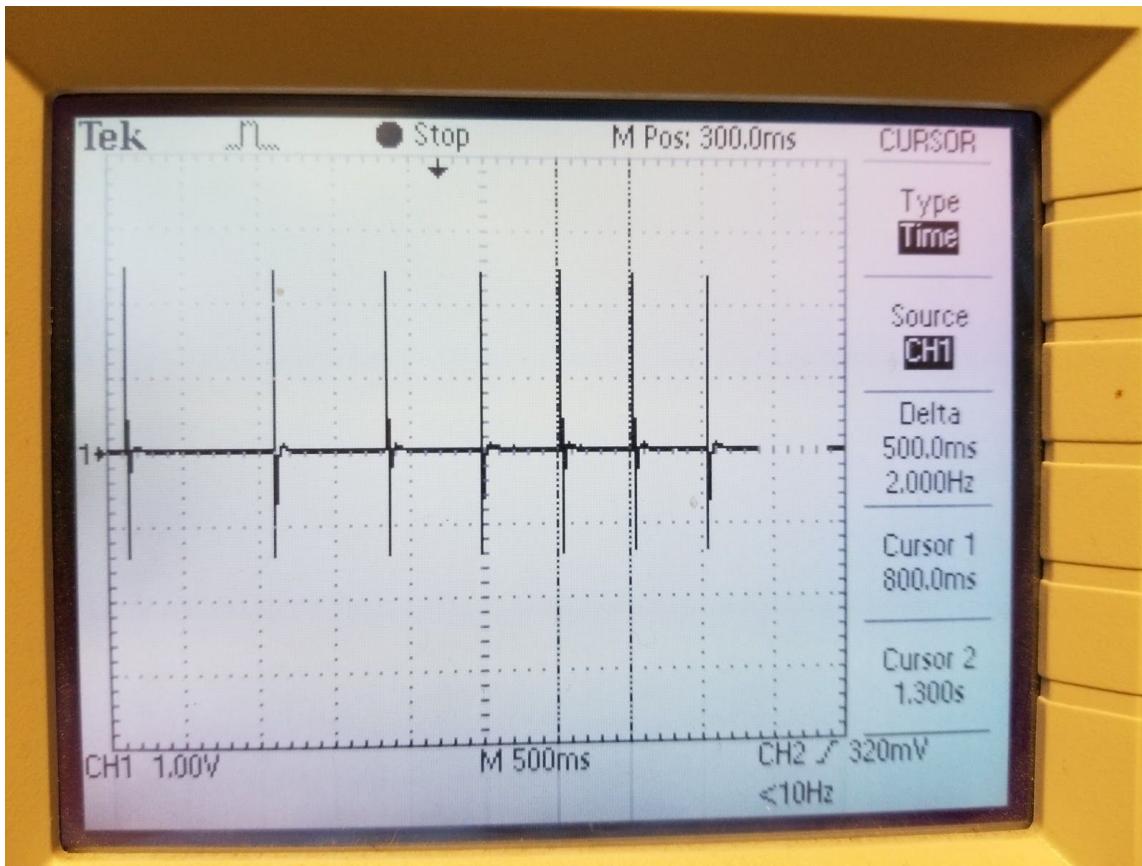




Result: Pass. Pacing period decreased gradually over time. Amplitude was ~10% from nominal input from imperfect contacts.

9.2. Test Case 2: Faster Ramp Up, Higher Amplitude





Result: Pass for increased rate change, fail for amplitude. Contacts should have been adjusted and the test repeated.

10. DOOR Testing

10.1. Test Case 1: Rate Ramp Up







Result: Pass. Rate increases gradually over time while keeping AV delay constant.